IMPLEMENTATION OF E-HEALTH INTEROPERABILITY IN DEVELOPING COUNTRY CONTEXTS: THE CASE OF ZIMBABWE

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SUMMARY

The provision of information technology-enabled healthcare services (e-health) has been adopted by numerous public and private facilities in both developing nations and advanced nations. However, one of the obstacles to the adoption of health information systems has been cited as their lack of interoperability resulting in their reduced effectiveness. In view of this, the study sought to explore the interoperability of health information systems employed in the country and then propose a framework to direct the process of implementing e-health interoperability. The study's methodology was qualitative and a case study was undertaken. Semi-structured interviews were employed to gather data from e-health stakeholders in state-owned institutions and private enterprises. Document review was also conducted to substantiate findings from interviews. Data was analysed using thematic analysis and NVivo 12 software. The study's findings revealed that several health information systems were implemented and their interoperability was low. Technological, terminology, organizational as well as regulatory and legal barriers were identified as hindrances to interoperability. The enablers for implementing e-health interoperability also revealed by this study include: development of re-usable software components, train the trainer approach to transfer of skills and regional conformance testing. The consequences of lack of interoperability among health information systems reported by this study include: burden on the worker, wastage of resources and high cost. The study also proposed a dual framework to guide the implementation of e-health interoperability. The study's recommendations include the development of an e-health policy, an e-health strategy and the upgrade of ICT and telecommunication infrastructure to facilitate health information exchange.

Key terms: e-health, electronic health information systems, interoperability, e-health interoperability

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DEDICATION

I dedicate this work to my husband Dzingayi, my sons Kudzai and Tadiwanashe, my daughters Sylvia and Kate, my mother Beatrice and my sisters Yvonne and Elizabeth.

DECLARATION

Student Number **58538259**

Declaration

I declare that **IMPLEMENTATION OF E-HEALTH INTEROPERABILITY IN DEVELOPING COUNTRY CONTEXTS: THE CASE OF ZIMBABWE** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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SIGNATURE DATE

(MS. M. MUHONDE)

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LIST OF ABBREVIATIONS AND ACRONYMS

AeHIN	Asian e-health Information Network
ATEHNA	Advanced technologies for interoperability of Heterogeneous Enterprise Networks and their Applications
CDA	Clinical Document Architecture
CDC	Centre for Disease Control
CPT	Current Procedure Terminology
DHIS2	District health Information System Version 2
EHR	Electronic Health Record
ePMS	Electronic Patient Management System
FEI	Framework for Enterprise Interoperability
FHIR	Fast Healthcare Interoperability Resources
GOe	Global Observatory for e-health
HIE	Health Information Exchange
HIS	Health Information System
HITRAC	Health Informatics Training and Research Advancement Centre
HIV/AIDS	Human Immunodeficiency Virus and Acquired Immune Deficiency Syndrome
HL7	Health Level Seven
ICD	International Classification of Diseases
ICT	Information and Communication Technology
IDEAS	Interoperability Development for Enterprise Applications and Software
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organisation for Standardisation
ITU	International Telecommunications Union
LIMS	Laboratory Information Management System
LMIS	Logistics Management Information System

LOINC	Logical Observation Identifier Names and Codes
MEASURE	Monitoring and Evaluation to Assess and Use Results
MoHCC	Ministry of Health and Child Care
PACS	Picture Archiving and Communication System
PFMS	Public Finance Management System
RTI	Research Triangle International
SDG	Sustainable Development Goals
SNOMED-CT	Systematised Nomenclature of Medicine Clinical Terms
TC	Technical Committee
UHC	Universal Health Care
UMP	Uzumba Maramba Pfungwe
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
WHO	World Health Organisation
ZHRIS	Zimbabwe Human Resources Information System

CHAPTER 1

INTRODUCTION

1.1 Introduction

Information and Communication Technologies (ICTs) are being used for delivering services in healthcare, hence the term e-health. Convenient, equitable and affordable healthcare services can be delivered to citizens through e-health. It is for this reason that governments of both developed and developing countries are investing in e-health (Furusa & Coleman, 2018). Farzianpour, Amirian & Byravan (2015) in Furusa and Coleman (2018) identify e-health as one of the rapidly growing areas in healthcare that can promote and strengthen health information and health systems. However, one of the key obstacles to the adoption of e-health is that health information systems are, in most cases, unable to interoperate, thus hindering the sharing of healthcare information (Adebesin, Kotzé, Van Greunen & Foster, 2013). Dogac et al., (2007) concur that the lack of interoperability among health information systems is a major challenge in healthcare informatics. For this reason, the potential of e-health to improve the provision of healthcare is hardly realised due to this lack of interoperability among health information systems (Adebesin, Kotzé, Ritz, Foster & Greunen, 2014).

Based on this need for interoperability, this research study aims to develop a framework for implementing e-health interoperability in a developing country context, using Zimbabwe as a case. It is anticipated this framework would be useful in providing guidance for implementing interoperable health information systems.

1.2 Background to the study

The importance of e-health lies in its ability to help reduce costs in delivering health services whilst providing better care. Omotosho, Ayegba, Emuoyibofarhe & Meinel (2019) posit that e-health can decrease the cost of collecting patient data by around 71%. According to the World Health Organisation (WHO) (2016) e-health refers to the secure and economical use of ICTs in the provision of health and health-related service including health literature, health care services, health education, health surveillance as well as knowledge and research. E-health strives to accomplish goal number three of the seventeen United Nations (UN)'s Sustainable Development Goals (SDGs) of 2015. Goal three is stated as, "To ensure healthy lives and promote well-being for all ages" (WHO 2016: 5). These SDGs are part of UN blueprint for "The 2030 Agenda for Sustainable Development". In addition, the World Health Organisation (2016) asserts that e-health plays a vital function in achieving universal health coverage (UHC). E-health is crucial in achieving target eight of SDG number three which is to "achieve universal health care" (WHO 2016:5). In this context, universal health coverage aims at ensuring that everyone receives high quality health services that they require without suffering financial hardship (WHO, 2016). Developing countries have populations that are amongst the highest worldwide, making the need for accessible, affordable and quality healthcare also high.

Thus, integrating ICTs in healthcare (e-health) is one avenue that can be used to address the healthcare needs of people in the developing world (Omotosho et al., 2019). According to Omotosho et al (2019) the general forms of e-health include m-health, telemedicine, electronic health records, tele-health, health information systems and health informatics for consumers. Among these several forms of e-health, this study focuses on health information systems, specifically, electronic health information systems. It is the interoperability of electronic health information systems that constitutes the focus of this study.

According to the Institute of Electrical and Electronics Engineers (IEEE) (1990), interoperability pertains to the capability of participating systems or elements to interchange data and then make use of the communicated data. If this capability is not accomplished, interoperability becomes a challenge that must be resolved Guedria (2015). Furthermore, Chen and Daclin (2006) acknowledge that establishing interoperability refers to connecting at least two systems together and then removing any incompatibility among them. In accordance with the International Telecommunication Union (ITU) (2017) the term interoperability means the capability of participating systems to inter-relate while sharing data. In this context, communication occurs in a non-ambiguous way so that data is exchanged accurately, consistently and effectively. With interoperability systems and applications that are technically disparate and managed by different organisations are expected to exchange data precisely.

Although nowadays it is possible to electronically access one's banking information, pay bills and withdraw money, from any part of the world, the same is not possible with regards to accessing healthcare information (Adebesin et al., 2014). However, interoperability is not yet mature in healthcare where access to patient information and other health information is readily accessible and usable as in the banking sector. The same kind of interoperations are envisioned to take place in e-health between patients and healthcare service providers. On the contrary, patients' healthcare data is difficult to access across different locations in the same town, worse still in the same country, hence making interoperability in healthcare systems a critical need (Kuziemsky et al, 2009).

Mansoor and Majeed (2010) conceptualise e-health interoperability as the communication and exchange of patient data and data about the health system accurately, securely, effectively and consistently with different information systems, software applications and networks in such a way that the meaning of the data is preserved and unaltered. Omotosho et al. (2019) assert that in Africa, patients' records are frequently fragmented, unconnected and are scattered among several public and private health facility platforms. The same is also true about the Zimbabwean healthcare system. This situation creates a problem that restricts accessibility and sharing of patient information, thus the interoperability problem has emerged.

Adebesin, Foster, Kotze & Van Greunen (2013) note that quality and effective healthcare services are facilitated by the ability of health information systems to share and exchange information that is, interoperate. Kalra (2006) in Masuku (2019) agrees that in order to achieve improved and efficient health services delivery, health information systems must be interconnected with systems of other providers for healthcare, thus, the notion of interoperability. Patients regularly receive healthcare from multiple service providers including health practitioners, health insurance funders and specialist medical services like radiology and medical laboratory services. This results in the disintegration of patients' healthcare records and profiles across several locations that are not interoperable or interconnected. This disintegration yields gaps and inconsistencies in patient data which makes it difficult for the clinician to provide better healthcare to the patient.

According to Adebesin et al. (2014) the use of ICTs in healthcare is characterised by silo systems whereby individual health facilities or providers have their own proprietary systems that cannot exchange healthcare information with the systems employed by fellow healthcare providers. The problem of fragmented e-health systems that cannot interoperate exists in both developed and developing countries (Adebesin et al., 2014). Mwakilama, Chawani, Monawe, Kapokosa & Gadabu (2014) concur that non-interoperable electronic healthcare systems are a challenge that is present in developed and developing nations. Accordingly, at international level, initiatives such as the European Union e-health interoperability roadmap, Healthcare Information Technology Standards Panel (HITSP) in America (Adebesin et al, 2014) and the Canada Health Infoway (Kuziemsky, Archer & Peyton, 2009) were adopted to address interoperability challenges. E-health interoperability is at its infancy in developing countries, making it difficult for health practitioners to provide better care to patients, hence the need to research on how it can be implemented and accomplished. For instance, in Tanzania it was reported that close to 86% of the health information systems were not interoperable (Kajirunga & Kalegele, 2015). Ndlovu, Mars and Scott (2021) also reported that health information systems in Botswana predominantly lacked interoperability within and among the public and private sector e-health systems. For instance, the m-health applications and e-record systems were fragmented and thus not interoperable. Zimbabwe also faces the same challenge of non-interoperable e-health systems.

Zimbabwe has a number of e-health systems running in the country, however a literature search suggests that the interoperability of such systems has not been investigated. The national Electronic Health Record (EHR) system in Zimbabwe, known as Impilo, is a nation-wide Health Information System (HIS) that is designed to be interoperable with other healthcare systems such as medical laboratories, radiology as well as other national health information systems such as DHIS2 and ePMS (Zimbabwe EHR roadmap 2020-2023). This national EHR has been implemented in some healthcare facilities in the country, but, its actual interoperability is yet to be documented (Zimbabwe EHR roadmap 2020-2023). E-health interoperability has been implemented in other developing countries such as South Africa (Seebregts et al., 2017), Rwanda (Crichton, Moodley, Pillay, Gakuba & Seebregts , 2013) and Tanzania (Nsaghurwe et al., 2021), however, its implementation in Zimbabwe appears not to have been investigated. This research study suggests a framework for implementing e-health interoperability in developing countries using Zimbabwe as a case study.

Despite several e-health systems employed in Zimbabwe, there is no documentation on how interoperable these systems are, to date. In addition, literature on the implementation of e-health interoperability in Zimbabwe, is not available. Furthermore, e-health interoperability implementation, particularly the development of a framework to guide the deployment of e-health interoperability in Zimbabwe has not been investigated. In lieu of the benefits associated with e-health interoperability (Luna, Campos & Otero, 2019), this study postulates that the interoperability of health information systems will yield more benefits to public healthcare in Zimbabwe and that an interoperability framework would be valuable in the implementation process.

1.3 Statement of the problem

In Zimbabwe, electronic health information systems are being used in various health related functions such as pharmacy, laboratory, HIV/AIDS monitoring, radiology, accounting, human resources management and logistics, but these information systems are isolated and do not communicate with each other, and yet some of them use the same information or databases. For instance, the electronic District Health Information System (DHIS2) that was introduced in Zimbabwe in 2013 to facilitate the collection of health statistics only runs in government hospitals and is not connected to private health facilities yet they share the same patients. Pharmacies also run various standalone computerised systems that cannot track the medical history of patients. Various private hospitals and clinics run disparate health information systems and databases which are accessible to them alone. This scenario is commonly referred to as silo systems. According to Chawurura, Manhibi, Dijk & Stam (2019) in Zimbabwe e-health implementations are disunited, fragmented and characterized by isolated pockets of activities in the health space. Masuku (2019) concurs that there is not yet meaningful interoperability among the disparate health information systems being used in the Zimbabwean health sector. This results in e-health systems existing as heterogeneous and disparate systems that do not communicate with each other. In this regard, patient records are only available at the facility that offer them health services and cannot be accessed by other care givers unless the medical record is in the form of a book that the patient carries around, each time they seek medical attention.

The consequences of a lack of interoperability among health information systems include, among others, burden on the health worker and administrators (Fanta and Pretorius, 2018); data discrepancy; redundancy where data is captured more than once into various information systems that are disease specific or targeted for certain distinct programs and departments (Zimbabwe EHR Roadmap 2020-2023); limited shareability of patient health record (Zimbabwe EHR road map 2020-2023); wastage of resources (ITU,2017) and disruption from building national health information systems and infrastructure (ITU, 2017). If these individual health information systems are made to interoperate, it could result in several benefits to the patients, the care givers and the nation at large, thus improving the quality of healthcare given to citizens.

The problem statement for this study is summarized as: There are several electronic health information systems that share the same patients and data but do not interoperate. This results in various consequences to the patients, the health workers and the nation at large.

1.4 Research aim

The goal of this research study was to develop a framework intended to provide guidance (best practices) for implementing e-health interoperability in developing country settings, using Zimbabwe as a case.

1.5 Research objectives

The objectives that guided the study were to:

1. Determine the current status of e-health implementation in Zimbabwe;
2. Determine the current status of e-health interoperability in Zimbabwe;
3. Determine the barriers in the implementation of e-health interoperability in a developing country context;
4. Determine the enablers in the implementation of e-health interoperability in a developing country context;
5. Identify consequences of a lack of interoperability in a developing country context;
6. Develop a framework for implementing e-health interoperability in a developing country context.

1.6 Justification of the study

Kajirunga and Kalegele (2015) state that system interoperability is crucial in accomplishing good health services delivery. However, in developing countries like Zimbabwe, e-health is still at the stage of "sensitisation, testing, amending and small-scale implementation" (Chawurura et al, 2019:2); thus implying that e-health interoperability is also at that level. Therefore, a framework for implementing e-health interoperability is crucial to guide its successful implementation, so as to avoid pitfalls. Accordingly, because new health information systems are being developed, an implementation framework would go a long way to ensure conformance to interoperability requirements as prescribed by the framework. Since Adebesin et al (2013) reported that e -health interoperability and its level of adoption level in Africa (including Zimbabwe) is insufficiently researched with minimal or no published research; findings from this research are intended to contribute towards the knowledge base on e-health interoperability in Zimbabwe.

1.7 Significance of the study

This research study's findings add to the existing body of knowledge of e-health interoperability in a developing country context. In addition, the proposed framework for implementing e-health interoperability is meant to guide developing countries and their health ministries when implementing electronic health information systems that are interoperable. The following stakeholders will benefit from this research study on e-health interoperability:

- Governments and health Ministries

The framework for implementing e-health interoperability provides guidance on best-practices when implementing e-health interoperability.

- Developers of e-health systems

  The framework acts as a yardstick for developers especially with issues concerning standards expectations and compliance to e-health strategy and e-health interoperability regulation.

- Patients

  With e-health interoperability patients' health information can be shared amongst different care givers regardless of the current location for both. This means patients can be quickly diagnosed. Shared patient health records results in reduced costs of healthcare since it eliminates the need for certain scans and laboratory tests which can be accessed from repositories or health portals, in an interoperability scenario. Patients can also receive reminders concerning significant activities such as review dates since these can be simply integrated on a health information system.

- Health care givers such as doctors, nurses, laboratory experts and others

  If patient health records become highly accessible, healthcare practitioners also access current information concerning their patients, who sometimes might have visited other health facilities prior to the current one. In addition, considering Zimbabwe`s health delivery system which consists of four levels (primary, secondary, tertiary and quaternary) a patient can move within this system seeking medical attention for one or more ailments. Accordingly, it is essential for care givers to have immediate access to patient health records, so that treatment can be accelerated and thus avoid consequences that originate from inadequate patient medical history.

- Academia

This research study will complement the present body of knowledge on e-health interoperability by presenting a dual framework for implementing e-health interoperability in a developing country context as well as identifying and discussing issues of e-health interoperability in developing countries.

- E-health interoperability practitioners

This study will also assist e-health interoperability practitioners with working domain knowledge on the theoretical underpinnings of interoperability namely the interoperability barriers (technological, organisational as well as legal and regulatory) that are likely to be encountered when implementing interoperability in e-health. Furthermore this study highlights the interoperability approaches (loosely coupled and closely coupled approaches) options that exist and guide practitioners with practical choices.

The practical contributions such as enablers in the implementation of e-health interoperability and consequences of lack of interoperability in e-health are also valuable to stakeholders when implementing interoperability in e-health.

1.8 Research methodology

The study was of a qualitative nature and pursued the interpretivist research philosophy in which knowledge is based on human experiences. In this regard the developed framework for implementing e-health interoperability was informed by data collected from the study's respondents. The case study research design was applied and qualitative data was collected using semi-structured interviews as well as document analysis. The following specific respondents were interviewed; relevant personnel from the Head office of the Ministry of Health and Child Care (MoHCC); e-health systems developers (from state-owned institutions and private enterprises) as well as health informatics specialists.

This research study conducted semi-structured interviews and undertook document analysis to ascertain the current status of e-health and e-health interoperability in Zimbabwe. Based on the Framework for Enterprise Interoperability, this research established the status of e-health interoperability in the country. The research study then identified barriers and enablers in the implementation of e-health interoperability. A framework to guide the implementation of e-health interoperability was then proposed and consequences of a lack of e-health interoperability were discussed. The data collected was analysed and major findings were presented. The study concluded by suggesting recommendations on implementing e-health interoperability in a developing country context and proposing directions for future research.

1.9 Data analysis

Thematic analysis was conducted on the gathered qualitative data. NVivo 12 software was used to perform a thorough qualitative data analysis thematically.

1.10 Thesis outline

Chapter two focuses on reviewing the related literature and elaborates on how the theoretical framework informed the conceptual framework. Chapter two also discusses literature on e-health, e-health interoperability, barriers and enablers for e-health as well as effects of lack of e-health interoperability. Empirical studies on these sub-topics were reviewed and the status for each of those in Zimbabwe was also presented. Chapter three is the methodology chapter and consists of the research philosophy, research design and the research study approach. This chapter also deliberates on the population, instruments and the data collection procedure. Chapter four focuses on the results and the discussion of the study's outcomes in the context of the research problem and the study's objectives. Chapter five presents the findings of the study and proposes recommendations for implementing e-health interoperability in a developing country context. This chapter concludes by suggesting future research directions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses literature related to e-health interoperability. The broad topics discussed in this chapter are health systems, e-health and interoperability. The chapter starts by describing the health system in terms of its components and the WHO framework for health systems strengthening in developing countries. The status of the health system in Zimbabwe is also articulated with regards to burden of disease, the nation's health priorities as well as the achievements and challenges in its health sector. With regards to general e-health issues the chapter discusses categories of e-health systems, WHO's global diffusion of e-health, an overview of e-health systems implementation in Zimbabwe and finally a discussion on the sustainability of e-health implementations. Interoperability issues constitute the greatest part of this chapter. Concerning interoperability, the issues presented are an introduction of interoperability initiatives, an introduction to Standards as well as a discussion of interoperability architectures such as the Open Health Information Exchange (OpenHIE).

2.2 Health systems

The World Health Organisation (2010b) postulate that a health system comprises resources, practices, people, and organisations whose main goal is to improve health. The primary purpose of both public (government) and private health institutions is to promote, restore and maintain health. Funds, workforce, provisions (medical and non-medical), information, communication, transport as well as overall guidance and direction are necessary for a health system to operate properly. A health system also has defined goals or outcomes. The World health report of 2000 in WHO (2007) defined the outcomes of general health systems as: enhancing health services and equality of access to health using means that are cost-effective and responsive while efficiently using the available resources.

2.2.1 Components of a health system

A functional health system comprises certain key elements which are also referred to as the health system's building blocks. According to WHO (2010a) the key components of a health system are leadership and governance, health financing, essential medical products and technologies, health information systems, human resources for health and service delivery.

<u>Leadership and governance</u>

Leadership and governance entail the role of the government in health matters as well as the relationship between government and other stakeholders in healthcare. The overall function of leadership and governance is that of "overseeing and guiding the whole health system, private as well as public, in order to protect the public interest" (WHO, 2007:33). In addition, making sure that strategic guiding principles and appropriate regulations are in place are also issues incorporated under leadership and guidance. In the context of leadership and governance WHO (2007) has the following priorities; to develop health sector policies and frameworks, regulatory frameworks, accountability, generate and intercept intelligence, build coalitions and work with external partners.

Health financing

An ideal health finance system thrives to raise sufficient financial resources in a manner that ensures those in need can access medical services at affordable prices. WHO also assists countries with improving their individual procedures of collecting data as well as integrating analysis of health expenditure and disastrous spending by governments. The key objective of health financing is to aid universal provision of health services by eliminating financial obstacles to access while avoiding unnecessary expenditure.

Transparent operational rules that guide the efficient use of funds is one sign of a good financing system. In terms of health financing, WHO's priorities are health financing policy, improvement or development of pre-payment of risk pooling, ensuring sufficient funding from domestic sources, promotion of international dialogue, used funds and increased availability of key information (WHO, 2007).

Healthcare workforce

The healthcare workforce refers to the collective of individuals whose primary role is the provision and improvement of health known as health workers namely; health services providers, health management personnel and support staff. Generally, the health workforce consists of government employees and private healthcare workers, paid and voluntary employees as well as the professional and unprofessional health work force. For any country, a "well-performing" health workforce is one that is characterised by their availability, competency, responsiveness and productivity (WHO, 2007).

WHO (2010a) stated that although different nations are at different levels of development in terms of their health workforce, they tend to share the same challenges usually associated with training and distribution, education, improving productivity and performance, improving recruitment and improving retention. According to WHO (2010a) these challenges can be addressed by offering competitive incentives and implementing a needs-based deployment personnel, among other strategies. According to WHO (2007), the focus of WHO has been on training, particularly in-service training. The health workforce priorities for WHO are named as: international norms, standards and databases, countries with a health workforce crisis, realistic strategies, costing, training, evidence, advocacy and working with international health professions groups (WHO, 2007).

<u>Health information systems</u>

An ideal health information system is characterised by ensuring the "production, analysis, dissemination and use of reliable and timely health information by decision-makers at different levels of the health system, both on a regular basis and in emergencies" (WHO, 2007:18). The three domains addressed by this building block are health determinants, health systems performance and health status. Health information systems are vital for reporting the performance of the health system. Epidemiological surveillance and civil registration issues are other pertinent aspects that are also addressed by health information systems.

WHO does not only evaluate the performance of health information systems, but it also assists member countries by providing a supportive role. In addition, WHO plays an active role in developing tools and standards such as the International Classification of Diseases (ICD), maintaining the database for global mortality and causes of death as well as producing regular reports on health statistics (WHO, 2007). WHO's priorities for health information systems are reporting, national information systems, stronger national surveillance and capacity, tracking performance, standards, methods and tools, as well as synthesis and analysis of country, regional and global data (WHO, 2007). This research study's focus is implementing e-health interoperability in a developing country context, which is aligned with the health information systems building block for health systems, as defined by WHO.

Essential medical products technologies

Availability of affordable essential medications, diagnosis and quality technologies for healthcare are the drivers of universal access to healthcare. A good health system ensures fair access to vital, safe and cost-effective medical products and technologies. For most health budgets, medical products constitute the second highest cost item (after salaries). In terms of essential medical products technologies, WHO is well-known for promoting well-informed procedures for selecting medicines, vaccines and technologies through the development of international standards and guidelines via its Expert Committees together with the process of consultation. WHO also provides information on the prices of medicines and vaccines as well as supporting post-marketing surveillance systems. The priorities for essential medical products technologies as suggested by (WHO, 2007) are: to establish norms, standards and policy options; procurement; access and use; quality and service as well as new products.

Service delivery

A good health service is one that delivers safe and quality health interventions to those who need it at the right time and place while ensuring minimum wastage of resources. Services delivered in the health system can be in the form of prevention, treatment, or rehabilitation. According to WHO (2007:14) "effective provision requires trained staff working with the right medicines and equipment and with adequate financing. Success also requires an organizational environment that provides the right incentives to providers and users". WHO (2007) states that priorities for the service delivery are; integrated service delivery packages, service delivery models, leadership and management, public safety and quality of care, infrastructure and logistics as well as influencing demand for care.

2.2.2 WHO framework on strengthening health systems in developing countries

Health systems strengthening, abbreviated HSS, refers to all efforts towards improving the healthcare system of a country through ensuring the provision of the health system components identified earlier (WHO, 2010b). Since an ideal health system needs funds, information, staff, medical supplies, transport and leadership in order to function, strengthening health systems therefore involves methods of addressing limitations in each of these spaces (WHO, 2010b). The World Health Organisation's approach to strengthening health systems basically refers to the six health systems building blocks or components of a health system discussed earlier. These components are namely: service delivery, health workforce, health information systems, access to essential medicines, financing as well as leadership / governance. WHO's health systems framework is composed of the six core building blocks. Figure 1 below depicts the WHO's framework for health systems.

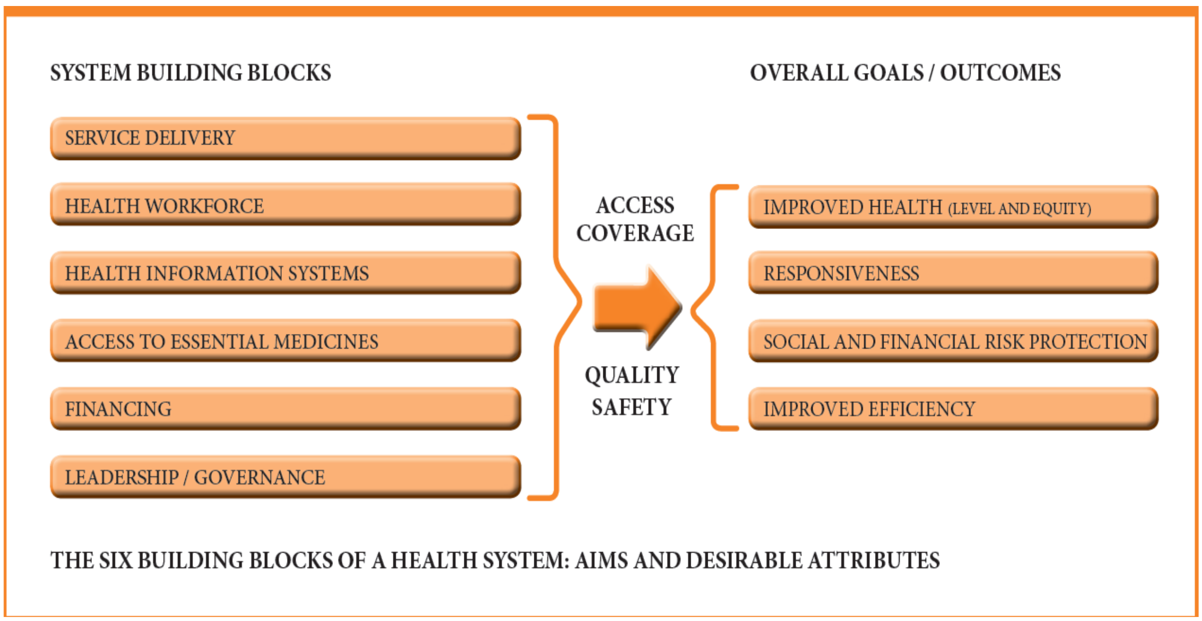

Figure 2.1: WHO's health systems framework

Source**:** WHO (2010b:vii)

The six building blocks add to the strengthening of health systems in various ways. Major input ingredients to the health system comprise of the healthcare personnel and funding. Instant outcomes of the health system, that is, accessibility of healthcare, are represented by essential medicines and service delivery. Administration and information systems for health are cross-cutting elements that act as the foundation for policy and regulation of all the health systems building blocks. According to Shakarishvili et al. (2010:6) "the building blocks approach is a useful means for locating, describing and classifying heath system constraints, for identifying where and why investments are needed, what will happen as a result, and by what means the change can be monitored". As nations strive to provide better healthcare to citizens, a list of pointers or indicators is essential in guiding the direction of improvement. WHO (2010b) recommended key indicators for each of the health systems building blocks as shown in Table 2.1.

Table 2.1: Recommended key indicators of the health systems building blocks

Building block	**Indicators**
Delivery of health service	Number and distribution of health facilities per 10 000 population
	Number of outpatient department visits per 10 000 population
	General service readiness score for health facilities
	Proportion of health facilities offering specific services
	Number and distribution of health facilities offering specific services per 10 000 population
Healthcare personnel	Number of health workers per 10 000 population
	Distribution of health workers by occupation/specialization, region, place of work and sex.
	Annual number of graduates of health professions' education institutions per 10 000 population, by level and field of education
Health information	Health information systems performance index
Vital medications	Average availability of 14 selected essential medicines in public and private health facilities

	Median consumer price ratio of 14 selected essential medicines in public and private health facilities
Health financing	Total expenditure on health
	General government expenditure on health as a proportion of general government expenditure (GGHE/GGE)
	The ratio of household out-of-pocket payments for health to total expenditure on health
Leadership and governance	Policy index

Adapted from WHO (2010b)

2.2.3 E-health as a component of Health systems

E-health systems are implemented within the context of the broader health system. This broader context affects e-health implementation and furthermore e-health can be used for strengthening a health system. E-health interoperability, the area of study, is a subset of e-health implementation. Sustainability of health programmes in low income and developing country contexts is an issue because of challenges that are often encountered in developing country contexts. Examples of programmes where sustainability was an issue are HIV treatment programmes in Africa, tuberculosis treatment programmes in Latin America, and implementation of community health workers programmes in inner city settings in the USA (Einterz, Kimaiyo, Mengech, et al., 2007; Farmer, Bayona, Bacera, et al., 1998; Shediac-Rizkallah & Bone, 1998). Challenges in implementation of ehealth systems in developing countries are reported in the following references (Blaya, Hamish & Holt, 2010; Cohen, Coleman & Abrahams, 2015; Osheroff, Teich, Middleton, et al., 2007).

Schneider and Daviadud (2012) report that the majority of e-health interventions that are deemed successful in low and middle-income countries and are founded in non-governmental organisations. Usually these e-health involvements are also not incorporated into the mainstream of government health services. The problems of system assimilation are worsened by the position that assessments of e-health initiatives have a tendency of focusing on viability instead of cost-effectiveness and impact, hence making it challenging to determine benefits.

2.3 Zimbabwe's health system

Zimbabwe is a landlocked country in Southern Africa which occupies 386 850 square kilometers (JICA, 2012) and has a population of 16.5 million people (CDC, 2019). Approximately 67% of the populace are rural residents whilst 33% are urban inhabitants. The nation has a total of 10 provinces that are sub-divided into 63 districts. The Zimbabwean population receive healthcare from hospitals and primary health care facilities that belong to the government. These facilities include those belonging to the security sector (namely, the army, police and prison health care centres), mission facilities as well as private health facilities. The government, municipality and mission health centres service the majority of the population.

According to the National Health Strategy for Zimbabwe (2016-2020) the country has a total of 1634 health facilities ranging from rural health centres to central hospitals. Zimbabwe's healthcare system comprises 4 levels of service provision (also known as the referral system) in a pyramidal structure namely primary health facilities, secondary level, tertiary level and quaternary level (National Health Strategy for Zimbabwe, 2016-2020). The lowest level is the primary health facilities (rural health centres or clinics) administered at village or ward level. The next level is the secondary level (district hospital) administered at district level. Mission hospitals play a significant role in providing healthcare at both the primary and secondary levels. Third on the pyramid is the tertiary level (provincial hospital) that provides general medical services. A provincial hospital is also a referral focal point for the district hospitals and clinics in a given province. The fourth level is the quaternary level which is comprised of central hospitals which are referral hospitals for complex problems and specialist care. Mission health facilities offer significant services mainly in rural areas while private health institutions mostly cater for the urban residents.

According to the National Health Strategy for Zimbabwe (2016-2020), Zimbabwe's government expenditure on healthcare is generally low. Since 2009 health funding by the government has improved to reach a peak of 8% of total government's expenditure in 2012. Still this figure (8%) is lower than that stated in the Abuja declaration of 2001 in which African Union countries pledged to commit 15% of their total government expenditure to health (WHO, 2010b) Significantly, also regarding government's funding towards healthcare, Zimbabwe was at USD$25 per capita in 2015 which was far below the USD$86 per capita recommended by WHO (2018). The inadequate funding for healthcare has resulted in obsolete health facilities and equipment in Zimbabwe (JICA, 2012).

2.3.1 Burden of disease in Zimbabwe and the country's health priorities, successes and challenges

According to CDC (2019) the major health threat and the leading cause for death worldwide is HIV. This is prevalent in Zimbabwe which has an HIV prevalence that is moderately high at 15% amongst adults aged between 18 and 49 years. TB-related deaths are also high. (National Health Strategy 2016-2020). In addition, UNDP (2020) concurred that Zimbabwe has about 1.3 million HIV infected people and the rate of new contaminations each year is estimated at around 39 000 cases. UNDP (2020) also noted that Zimbabwe is on WHO's list of 14 nations that have a high prevalence of tuberculosis, multi-drug resilient tuberculosis as well as TB/HIV co-infection. Zimbabwe also has a high burden for Malaria, which is prevalent in certain geographic areas.

Communicable (transmissible) diseases and non-communicable diseases (those that cannot be transmitted from one person to another) also pose a public health challenge to Zimbabweans. According to WHO (2018) 31% of the deaths in Zimbabwe are as a result of non-communicable diseases. A growing number of people in Zimbabwe suffer from the following health conditions: hypertension, cancers, diabetes, mental health conditions, cardiovascular conditions and road traffic injuries.

The health situation in Zimbabwe has also been affected by a decade of high levels of inflation and economic deterioration leading to poverty. This resulted in the emigration of skilled human resources for health from the public sector leading to a severe shortage of a skilled health workforce which led to a close fall down of the health system in 2008. The exodus of skilled health workforce coupled with the declining health infrastructure are making it difficult for the government of Zimbabwe and its international partners to provide basic health services and fight HIV, TB and malaria. (UNDP, 2020)

According to the National Health Strategy (2016-2020), the provision of health services in Zimbabwe is guided by 4 health priorities which are further broken down into several specific objectives. Priority number 1 is communicable diseases and one of the objectives is to reduce the prevalence of Malaria from 39 people per 1000 in 2014 to 5 incidences per 1000 people in the year 2020. In addition, the target is also to reduce deaths from malaria to almost zero by the year 2020. Health priority number 2 is non-communicable diseases. These are diseases that cannot be transmitted from person to person. One of the objectives is aimed at reducing the incidents of selected non-communicable diseases by half. Health priority number 3 is reproductive, maternal, new-born children and adolescents. Objectives under this priority are centred on reducing maternal mortality rate, neonatal mortality rate, under five mortality rate and reducing mortality and morbidity as a result of malnutrition by 50%. Health priority number 4 is public health surveillance as well as disaster preparedness and response. The objective here is to reinforce environmental healthcare services, improve early detection of disease outbreaks as well as reduce outbreaks of man-made disasters from 30% to 50% by 2020.

Zimbabwe`s healthcare system heavily depends on external support especially with regards to the retention of Human Resources for Health. The purchasing of vital medicines and health technologies is also still being under-funded (WHO, 2018). The health system in Zimbabwe is affected by a considerable shortage of an experienced and skilled health workforce, resulting in a high vacancy rate especially in the public sector. This shortage is mainly due to emigration. In order to address this shortage, a Human Resources Retention Scheme has been put in place by the Global Fund and other donors. In this respect, health workers are being paid allowances as an incentive (JICA, 2012). The Zimbabwean health situation is exacerbated by poor water supply and electricity disruptions (JICA, 2012).

Despite the challenges affecting Zimbabwe's health system, there are some success indicators. The health supply system has greatly improved as a result of the support of donors (JICA, 2012). According to UNAIDS (2014) cited in the National Health Strategy (2016:15) "The HIV prevalence for adults (15-49 years) has declined by 5.6% from 2011, to 15% in 2014". On the same note concerning a decline in HIV prevalence, WHO (2018:1) concurred that "The country has experienced a gradual decline in HIV prevalence among adults aged between 15 – 49 years, from a peak of 29.7% in 1997, to 18.1% in 2006; and 14.7% in 2015, predominantly as a result of behaviour change". Furthermore, UNDP (2020) noted that new HIV infections declined by 80% among children born with HIV positive mothers and new infections dropped by more than 50% among adults over the last decade. In addition, AIDS-related mortality dropped by 60%.

Also, in the period 2011 to 2019 the TB incidence dropped by 67% from 633 to 210 cases per 10 000 people.

Although malaria is one of the diseases that forms part of Zimbabwe's burden of diseases, some improvements have been experienced. The prevalence of malaria fell from 58 per 1000 people in 2009 to 39 for every 1000 people in 2014, thereby meeting the Abuja target of a Malaria prevalence rate of 68 incidents per 1000 people (WHO, 2018). On the same issue, UNDP (2020) concurred that between 2015 and 2019, Malaria prevalence dropped by 24% from 29 to 22 per 1000 people at risk.

Zimbabwe was the country context for this study. Zimbabwe's profiles also fits that of a developing country context. The challenges related to e-health implementation experienced by other developing countries are the same as those being encountered in Zimbabwe. These include lack of ICT infrastructure, erratic power supply (Haque et al, 2019), lack of funding from governments to support e-health, lack of skilled manpower, absence of policies governing standards, terminology and messaging in e-health (Da et al, 2015)

2.4 E-health systems

"E-Health refers to tools and services using ICTs that can improve the management and monitoring of a health system and improve the prevention, diagnosis, and treatment for patients" (Oberer & Erkollar, 2013:1). In 2005 the 58th World Health Assembly (WHA) adopted the resolution WHA58.28 on e-health (WHO, 2016). Since then digital healthcare takes precedence for the World Health Organisation (WHO). According to WHO (2005) cited in Blaya, Fraser & Holt (2010:244) e-health is defined as “the use of information and communication technologies in (ICT) in support of health and health-related fields including health-care services, health surveillance, health literature and health education, knowledge and research”. Similarly, Abolade and Durosinmi (2018) define e-health as the use of ICT for providing health services offering healthcare functions such as clinical, research, education and administrative functions across different geographical locations. According to Gerber, Olazabal, Brown & Pablos-Mendez (2010:235) e-health “covers a broad range of tools such as electronic medical records (EMRs), telemedicine, health information systems, mobile devices, online or e-learning tools, and decision support systems”. From these definitions, it can be noted that e-health is a broad concept which involves the use of several elements for healthcare provision using electronic means. In this regard, e-health is generally considered a synonym for health informatics.

E-health has the capability of positively influencing the quality of care and improving efficiencies in healthcare (Adebesin et al., 2013). This potential of e-health was also supported by Blaya et al. (2010) who concurred that e-health has the potential to improve the efficiency of healthcare services and expand treatment delivery to numerous people in developing communities. This research study was limited to a form of e-health known as Health Information Systems (HIS), particularly, the interoperability of HISs.

According to WHO (2011) cited in Moucheraud et al. (2017:2), the term health information system (HIS) “refers to the collection, storage, management, processing and transmission of information within the health sector". Elements that constitute HIS include laboratory systems, district-level routine information systems, human resources management systems and disease surveillance systems, to name but a few (Moucheraud et al., 2017).

Health Information Systems are pertinent to a resilient health system. HISs constitute one of WHO's six building blocks of a health system (WHO, 2010b). According to Moucheraud et al., (2017), Health Information Systems support disease surveillance, patient and program management, strategic use of information and quality improvement. Many health Ministries in developing countries with the support of their partners such as the US President's Emergency Plan for AIDS Relief (PEPFAR) and United Nations Development Programme (UNDP), among others, have introduced electronic HIS which are perceived to be more efficient and quicker to respond as compared to paper-based systems (Moucheraud et al., 2017). In addition, HISs promote data legibility and data quality. Therefore, this research study focused on electronic Health Information Systems. In addition, the term Health Information Systems in this study implies electronic Health Information Systems.

2.4.1 Categories of e-health systems

There are different ways of classifying e-health systems in literature, this research study adopted the categories of e-health systems stated by Blaya et al. (2010). This classification was adopted because it corresponds to the systems typically used in developing countries, a category to which this research study also belongs. The presentation of these categories is not in order of priority. According to Blaya et al (2010) the categories of e-health systems are:

Electronic Health Record (EHR), laboratory information management systems, pharmacy information systems, patient registration or scheduling systems, monitoring, evaluation and patient tracking systems, clinical decision support systems, patient reminder systems as well as research or data collection systems. Each of these e-health systems will be discussed in the paragraphs that follow.

Electronic Health Record (EHR)

Blaya et al (2010:245) define an EHR as "an electronic record of health-related information on an individual that can be created, managed or consulted by clinicians or staff". Roman (2009) cited in Seymour, Frantsvog & Graeber (2012) concur that an electronic health record is a patient's health documentation that is generated, managed and held by a healthcare organisation. Access and use of an EHR are limited to only the healthcare professionals involved in the patient's care. EHRs typically consist of a number of functionalities, thus making them the principal clinical application in healthcare provision. According to Seymour et al (2012:201) "the core components of an electronic health record include administrative functions, computerized physician order entry, lab systems, radiology systems, pharmacy systems, and clinical documentation". The administrative function typically includes patient registration and demographics, computerized physician order entry which enables physicians to order radiology tests, laboratory tests and pharmacy services. The laboratory system is usually interfaced with the EHR and typically facilitates the placing of lab orders, scheduling and results exchange. The clinical documentation system constitutes the core of an EHR. This function allows health professionals such as doctors, nurses and physicians to record or document information about the patient such as clinical notes, medication, administration records, vital signs and discharge summaries. Another important EHR functionality is clinical decision support which enables doctors and nurses to “choose the correct course of action on a particular patient and his/her condition” (Seymour et al., 2012:205). The broad elements/functionalities of EHRs result in their implementations being complex and difficult. Evaluations of certain EHRs by Blaya et al., (2010) yielded that the majority of clinicians positively viewed EHR implementations and hence used EHRs more. This outcome was based on an evaluation of the Indian Health Service Vista system. It was also noted that EHRs had the ability to improve medical staff’s satisfaction and productivity. Based on an evaluation of an EHR in Kenya known as the Mosoriot Medical Record System, it was reported that EHRs improved patient care by providing higher quality data and also reduced patient waiting time (Blaya et al., 2010).

Laboratory Information Management Systems (LIMS)

Blaya et al. (2010) posit that Laboratory Information Management Systems (LIMS) ideally keep track of the activities of the laboratory and assist in reporting results to healthcare professionals. Skobelev, Zaytseva, Kozlov, Perepelitsa & Makarova (2011:1182) note that LIMSs are “used to control and manage samples, standards, test results, reports, laboratory staff, instruments, and work flow automation”. In terms of the functions of LIMS; Boyar, Pham, Swantek, Ward & Herman (2021) agreed that typical functions of LIMS include: sample receipts and sample log on, instrumentation integration, result entry, quality control samples, result reporting as well as archiving and data warehousing. In other words, the overall role of LIMS is to increase efficiency in laboratory related operations. The key benefits of LIMSs comprise of reduced times for communicating results as well as improved efficiency in laboratory workflows (Blaya et al., 2010).

Pharmacy Information systems

Pharmacy Information systems are those that are used for ordering, dispensing and tracking medications or medication orders (Blaya et al., 2010). Computerised order entry systems also belong to this category of HISs. According to Kazemi, Rabiei, Moghaddasi & Deimazar (2016:231) a pharmacy system can be defined as "a system that supports the distribution and management of drugs, identifying the type of intervention, determining the amount of inventory and managing of costs and improving the accessibility of information". Based on an evaluation study of health information systems in developing countries by Blaya et al (2010) the major benefits of pharmacy information systems were a reduction in errors and the ability to predict medication requirements.

Patient registration/patient scheduling systems

Patient registration, also known as patient scheduling systems, are another type of health information systems. These systems are used for monitoring and managing patients' movement through multistep processes (Blaya et al., 2010). An admission-discharge-transfer system is an example of a patient registration system. An evaluation study carried out by Blaya et al. (2010) of a patient registration system in Malawi, revealed that, despite the challenges associated with training and technical support as well as the need to uphold a parallel system, users preferred this electronic system.

Monitoring, evaluation and patient tracking systems also belong to this group of HISs. These systems are typically used for program monitoring, aggregate reporting of information and tracking of patients' status (Blaya et al, 2010). In this category belongs district health information systems, among others. The District Health Information System 2 (DHIS2) is an online and free platform that is widely used in a number of developing countries, including Zimbabwe. Garrib et al. (2008) cited in Dehnavieh et al (2019:63) state that the role of DHIS2 is to "aggregate routinely collected data across all of the public health facilities of a particular country, to facilitate analysis of health services provided in that country at the national level, forecast required services for future planning purposes and to evaluate the performance of healthcare workers".

Some of the benefits of using DHIS2 include high accessibility of information in the system from anywhere since the software is web-based. In addition, according to Dehnavieh et al., (2019), experiences of Uganda, Ghana and Kenya showed that workers' satisfaction with DHIS2 improved as a result of the efficient reporting abilities of DHIS2.

Clinical Decision Support Systems (CDSS)

Blaya et al (2010:245) define CDSS as "systems designed to improve clinical decision making in which characteristics of individual patients are matched to a computerised knowledge base and software algorithms generate patient-specific recommendations". According to Dinevski, Bele, Šarenac, Rajkovič & Šušteršič, (2011) the term clinical decision support systems refers to computer applications that are meant to assist healthcare professionals when making clinical decisions about individual patients. Clinical Decision Support Systems are quite beneficial in developing countries where there is inadequacy of trained clinical staff, especially in the rural areas (Blaya et al., 2010). The intended aim of CDSS is to enhance healthcare delivery by assisting with making informed clinical decisions using patient information and other health-related information. However, the adoption of CDSSs is relatively low due to the high cost of technological requirements. An evaluation of the Early Diagnosis and Prevention system in India performed by Blaya et al (2010) revealed that patients were highly satisfied if they were first seen by a computer operator before visiting the clinic. In addition, a huge number of new patients was also recorded at healthcare centres where the new system was operational. In Africa, there appears to be limited experiences in the use of CDSSs. In 2014, a project for the management of childhood illnesses known as the Integrated Electronic Diagnosis Approach (IeDA), was launched in two regions of Burkina Faso, using computers and tablets (Asiedu, n.d.). To date, about 606 healthcare facilities are running the IeDA.

Patient reminder systems

The purpose of Patient reminder systems is to evoke patients to perform a particular action such as attend clinic or take medication (Blaya et al, 2010). A Short Messaging Services (SMS) used as a vaccine reminder system has been used in Guatamala (a LMIC) to improve infant vaccination coverage and proved to be highly acceptable and yielded high user satisfaction (Domek et al., 2016). In South Africa, a text messaging-based reminder system was implemented to promote adherence to tuberculosis treatment. Higher completion rates of TB treatment were recorded as a result of using this system (Nglazi, Bekker, Wood, Hussey & Wiysonge, 2013). Based on an evaluation study carried out by Blaya et al (2010), it was revealed that due to the use of text messaging as well as mobile phone reminders, in Malaysia, attendance increased by 21% compared to the control group.

This section thus presented the major forms/categories of e-health systems including, laboratory information management systems, patient reminder system, patient registration or scheduling systems, Electronic Health Record (EHR), pharmacy information systems to mention a few.

2.4.2 WHO global diffusion of e-health

The 58th World Health Assembly adopted a resolution that endorsed Universal Health Coverage (UHC), that is, resolution WHA58.33. WHO (2005) cited in O'Connell, Rasanathan & Chopra (2014:1) described UHC as "access to key promotive, preventive, curative and rehabilitative health interventions for all at an affordable cost, thereby achieving equity in access". From that time both e-health and UHC have been advancing progressively (WHO, 2016).

WHO (2016) postulated that e-health is fundamental towards the accomplishment of universal health coverage. According to WHO (2016) e-health can promote UHC through m-health and tele-health by providing health services to remote communities and under-served populations, for instance e-learning enables the training of the health workforce while EHRs makes it possible for healthcare providers to efficiently diagnose patients and decrease medical errors as they provide better care.

The WHO global diffusion of e-health study was grounded on the outcomes of the third international e-health survey carried out by WHO's Global Observatory for eHealth (GOe) in 2015. The third worldwide review on e-health aimed to "explore developments in eHealth since the last survey in 2010 and the role it plays in achieving universal health coverage" (WHO, 2016:5). A high response rate was reported for the 125 WHO member states that participated in this survey. From this survey, it was also noted that e-health was essential towards the achievement of UHC. The GOe survey of 2015 was broken down into eight thematic areas namely e-health foundations, electronic health records, m-health, e-learning in health sciences, telehealth, social media, legal framework for e-health and big data. For this study, the global diffusion of e-health shall be discussed in terms of these focus areas.

E-health foundations

The successful implementation of e-health requires a solid foundation. According to WHO (2016) e-health foundations comprise of national policies and strategies, funding, multilingualism and capacity building. The outcomes of the 2015 Global Observatory for eHealth (GOe) survey revealed that 58% of the member states that responded, had an e-health strategy and that 91% (which is almost all) of these strategies indicated how e-health can support universal health coverage. In addition, 66% of the responding member nations had already adopted a national Health Information Systems (HIS) policy. These remarkable figures were an indicator that member nations understood the criticality of e-health strategy or national HIS since these lay down a national health system's vision and objectives to be followed in order to meet a nation`s health information needs.

In terms of funding, the GOe's survey of 2015 reported that sources of funding could be public, private, donor-funding or public-private partnerships. In addition, various combinations of these sources of funds can also be implemented. The trend was that, public funding for e-health programmes was dominant in high and upper-middle income countries where most developed countries belong. On the other hand, donor funding dominated in the low and lower-middle income countries where almost all developing countries belong, while a combination of public and donor funding characterised the upper-middle income countries.

Multilingualism is widely becoming a requirement since more than one language is spoken in almost all countries. In this respect, it is now highly expected that information about health and health service be available to nationals in a language that they speak and understand.

Linguistic diversity is one way in which a country can implement a national multilingualism policy or strategy. An example is the establishment of government-supported websites that deliver information in multiple languages. In this context, findings of the 2015 survey conducted by GOe were that about half (51%) of the countries had government-supported health websites that delivered content in various languages while 38% of the countries did not have that facility. Capacity building of the health workforce plays a very critical role in enabling nations to deliver e-health services that are of high quality.

The forms of e-health training considered in the 2015 survey were ICT for health training (pre-service and in-service) and social media for health (pre-service and in-service). It was noted that of the member states that participated in this survey, more nations (77%) offered in-service ICT training for health compared to those countries (70%) that offered in-service ICT training for health. With respect to social media training, 33% of the respondent nations offer social media for health training (pre-service) while 24% offer social media for health training (in-service). However, since the survey took place in 2015, about seven years ago, the situation might have improved considering the increasingly wide use of ICTs and social media in health.

M-health

Mobile health (m-health) denotes the provision of medical services using mobile devices such as smart phones. Numerous forms of mobile health applications exist including health call centres, reminder to attend appointments, clinical decision support systems and e-learning. Through making health services available in remote communities, m-health can assist towards attaining universal health coverage. An exponential increase in the usage of mobile devices has been observed, particularly in the developing world with mobile phone subscriptions rising from 1.2 billion to 5.5 billion in 2015. Based on the global survey conducted by WHO's GOe, the analysis of m-health usage was in terms of forms of m-health, level of adoption, role of national health authorities in m-health, evaluation of m-health programs and barriers to implementing m-health programs. The survey reported 14 forms of m-health programs which were categorised into communication between health services and individuals, inter-sectoral communication in emergencies as well as health monitoring and surveillance amongst others. Regarding the level of adoption of m-health programs, it was reported that the bulk of m-health programs operated at the national (across other facilities in the same country), or local levels (within a health centre providing basic care) and that few operated at international level (operating in other countries in the world).

Concerning the role of national health authorities in m-health, a 2015 global survey on e-health, revealed that 57% of the participating nations' governments sponsored m-health programmes implementations. Interoperability, promoting standards and regulating mobile devices a as well as providing guidance on privacy and security are additional functions that were also investigated by national health authorities.

The 2015 GOe survey also revealed that low and middle-income countries encountered significant barriers when implementing m-health programmes. This survey requested participating countries to rate obstacles to the implementation of mobile health programmes in order of their significance. The top two obstacles that were rated as very significant were absence of funding and lack of legal guidelines addressing mhealth. It was also noted that m-health programmes usually require significant initial investment to cover set up, operational and evaluation costs and the net benefits would be realised over time.

Tele-health

According to WHO (2016:56), telehealth is "the delivery of health care services, where patients and providers are separated by distance. Telehealth uses ICT for the exchange of information for the diagnosis and treatment of diseases and injuries, research and evaluation, and for the continuing education of health professionals". In terms of tele-health, the 2015 GOe survey reported on national tele-health policy or strategy, national tele-health programs and their evaluations as well as barriers to tele-health. Tele-health policies are important because they give direction on how set objectives can be achieved.

The 2015 GOe survey revealed that 22% of the country participants said that they had an exclusive e-health policy and 35% of the countries had tele-health enshrined in their national e-health policy or strategy. However, 42% of the countries did not have any guiding document for tele-health.

The survey recognised the following types of tele-health: tele-radiology, tele-dermatology, tele-pathology and remote patient monitoring. Responses from the participating countries revealed that a total of 375 tele-health programmes were operational globally. It was also noted that each country reported an average of about 4 tele-health programmes out of the 5 identified by the GOe. The survey also found that the major barriers to the implementation of tele-health were insufficient funds for developing and supporting tele-health programmes, absence of legislation or regulation that addresses tele-health, competing health system priorities as well as unavailability of infrastructure (equipment and connectivity).

E-Learning in health sciences

E-learning refers to the delivery of learning and training through digital resources. E-learning is increasingly being considered for the training of health professionals. The GOe survey of 2015 reported on the status of e-learning, the barriers for health sciences education, the various e-learning applications and the extent of adoption. It was reported that over 60% of the participating countries made use of e-learning for purposes of training, in the field of health sciences. The two dimensions of training that were covered by the survey were pre-engagement training and in-service training.

The Pre-service health sciences training category consists of undergraduate programmes, university degrees related to health sciences, vocational training programmes that are acknowledged by the government or relevant professional bodies for junior or elementary positions in the healthcare domain. Professional development training in health sciences denotes a field of study where further training is offered to an already practicing health professional, so that they can work in a more senior role.

Out of the 125 member states that participated in this survey 65% testified that e-learning was being used for training health sciences students prior to joining the medical profession. On the other hand, only 26% of the countries did not use e-learning for pre-service training in health sciences. Generally, the use of e-learning was more commonly reported for in-service training across all the WHO six regions as compared to pre-service training. Despite this seemingly commendable uptake of e-learning for training health sciences students, a number of barriers affected its wider implementation. These obstacles included human resources, lack of capacity, funding, availability of suitable e-learning courses as well as evidence regarding the cost-effectiveness of e-learning.

Various e-learning applications or options could be adopted to address the identified key hindrances to e-learning such as funding, lack of suitable courses and capacity. Free, shareable and peer-reviewed e-learning materials available through Massive Open Online Courses (MOOCs), Free Open Source Software (FOSS) and Open Education Resources (OER) could be adopted in this regard. Low income countries can consider the twinning strategy. In countries with capacity challenges, blended e-learning coupled with face-to-face training could be adopted to ensure the development and acquisition of clinical skills.

Despite the benefits and opportunities offered by e-learning in medical sciences, the following challenges were noted in a developing country context, insufficient capital inadequate knowledge pertaining access and usage as well as poor skills (Noorbhai and Ojo, 2023).

Electronic health records

The GOe survey of 2015 focused on national EHRs systems. These are owned, driven and funded by the government. EHR systems are significant in that they promote quality of care, support patient mobility, reduce costs and provide multiple health care providers with access to patient information.

As far as national EHRs are concerned, the GOe survey of 2015 covered the implementation of national EHRs, legislation issues, integration with other HISs and barriers to implementation. The 2015 survey revealed that the adoption of national EHR systems had experienced a steady growth over the past 15 years with most high-income countries showing a higher rate of adoption compared to low-income countries. Funding was identified as the major reason behind this slow uptake in developing countries. The survey revealed that 47% of the responding member states had a functional national EHR, whilst 52% did not have. It was also reported that over 50% of high-income and upper-middle countries had implemented national EHR systems. On the other hand, lower-middle and low-income countries had lower adoption rates of 35% and 15% respectively. Although 56% of the countries reported that they had specific legislation for national EHR, almost half (43%) of the countries said they did not have appropriate legislation for national EHRs.

In the survey, participating member states also reported the incorporation of EHR systems with some health information systems. The prevailing order of integration was; EHR and laboratory systems 77%, EHR and pharmacy systems 72% and finally EHR and Picture Archiving and Communications Systems (PACS) 56%. The survey also identified the major obstacles to the deployment of EHR systems as infrastructure, insufficient financial resources, capability and legal framework. These were more severe in low-income countries compared to other regions (WHO, 2016).

Legal framework for e-health

The legal framework for e-health is broad and stretches from basic data privacy guidelines to other complexities like technical interoperability. The 2015 GOe survey also covered legal aspects related to Electronic Health Record (EHR) usage and how stored data in EHRs could be exchanged. Responses gathered for this section of the survey on legal frameworks for e-health, complemented responses from m-health, tele-health and EHRs concerning whether legal issues were an obstacle to the adoption of those e-health initiatives.

In terms of legal frameworks for e-health, the 2015 GOe survey reported on the legal baseline of e-health, the privacy of patient data and the exchange and use of health-related data (WHO, 2016).The legal baseline was presented in two parts. It was reported that 33% of member states who participated in the GOe of 2015, had legislation or regulation to describe the medical jurisdiction or liability of e-health services whilst 63% did not have. In terms of privacy for patient data, more than three quarters (78%) of the participating countries reported the existence of some form of privacy legal statutes meant for the protection of personal data, with higher rankings found in the European region. Concerning the existence of legislation that covers the privacy of EHR health-related data, only 55% said they had such legislation.

Although this figure is not high, it shows great improvement in legislation that addresses EHRs privacy protection, which considerably increased from 31% in the 2010 GOe survey to 55% in the 2015 GOe survey. Despite advances having been made in terms of legal frameworks for e-health since the 2010 GOe survey, more work needs to be done globally, especially focusing on developing countries. In support of the need for a legal framework for e-health, Mengiste et al (2023) concurred that proper e-health policies reduce data safety concerns, increase accountability and simplify interoperable EHR standardized exchange while upholding data integrity. Furthermore, in order to facilitate commendable policy adoption by healthcare providers, health ministries can offer incentives such as paying for adoption costs, covering implementation costs as well as compensating where good performance is evident, in low resource settings (Mengiste et al, 2023).

Social media

Social media is nowadays being widely used in all spheres of life, including healthcare. With respect to social media, findings of the 2015 GOe were presented in terms of national policies / strategies, use of social media by health organisations and usage of social media by individual people and societies. The 2015 GOe survey reported that only 19% (n=23) of the participating countries had a national policy document or a national strategy for social media usage while 68% had none.

The survey findings revealed that healthcare organisations used social media for the following purposes; help manage patients' appointments, seek feedback on services as well as announce emergencies and general health matters. It was also reported that almost 80% of the participating countries use social media for promoting health messages and that more than 62% of the participating members, use social media for running community-based health campaigns (WHO, 2016). Since social media is very dynamic, the government and relevant health stakeholders need to urgently and critically examine the social media policy frameworks including issues of privacy and confidentiality while using social medial.

<u>Big data</u>

Big data refers to a huge volume of variable and oftentimes complex data that requires computational techniques for it to be disseminated, managed and analysed (Tabassum, 2018). Although big data is becoming widely used in all sectors of life, it appears to be relatively new in the health sector. Data generated from public health, clinical operations and device/remote monitoring appears to constitute some of the big data sources in healthcare. Based on the 2015 GOe survey, it was reported that only 17% of the participating countries had a policy/strategy for big data. Results of the survey showed that lack of integration as well as security and privacy were the key impediments to the adoption of big data for supporting universal health care. The 2015 survey also highlighted significant risks and gaps in big data usage that required consideration. These included amongst others: standards development, privacy, capacity building, information sharing and integration. Some of the implications associated with big data are high costs of data storage (Hong et al, 2018), data protection and analytical flows in analysing data (Pastorino, et al 2029).

The enormous volume of healthcare big data now in petabyte has gone beyond the capabilities of PCs and network file sharing programs, hence requiring new file sharing mechanisms. The voluminous nature of health data arises from the diverse data types that include numerical data storing disease tests, numerous diagnostic images, speeches and videos made by doctors and nurses (Hong et al, 2018). With respect to data sharing big data lacks uniform standards, consistent description format and presentation methods, thus limiting data standardization and interoperability.

2.4.3 Overview of e-health systems implementation in Zimbabwe

Numerous e-health systems have been deployed in Zimbabwe, just like in most developing countries. Some of these systems are national systems that are used in the majority of public health facilities such as electronic Patient Management System (ePMS) and DHIS2 whilst others are dominantly used in the private sector. There are three major electronic health information systems that have been implemented and operating at nation-wide level, namely the District Health Information System 2 (DHIS2), the electronic Patient Management System, and the Public Finance Management System (Chawurura, Manhibi, van Dijk & van Stam, 2019). The Ministry of Health and Child Care (MoHCC) with the support of its partners namely UNDP in collaboration with US President's Emergency Plan for AIDS Relief (PEPFAR), Research Triangle Institute (RTI) and United Nations International Children's Emergency Fund (UNICEF), implemented DHIS2 in all the government district and provincial hospitals in Zimbabwe in 2013 (UNDP, 2020). According to UNDP (2020) DHIS2 has been implemented to date in 63 district hospitals, 10 provincial hospitals, 4 city health facilities as well as the national Ministry of Health offices. DHIS2 is an aggregate system that allows users at all levels to view data immediately after being captured by health officials. This has since resulted in great improvements in timely reporting and informed decision-making. Using DHIS2 made it possible to develop an integrated national data repository for integrating data from various disease-specific programmes. The Weekly Disease Surveillance together with 13 program databases such as the Village Health Worker Form, Psych, Morbidity and Mortality Information System, Early Infant Diagnosis and Rehab have been integrated into the DHIS2 since its implementation (UNDP, 2020). There are on-going efforts to incorporate all parallel systems into DHIS2 and ultimately into the national EHR. The Ministry of Health and Child care (MoHCC) with the support of UNDP, was able to develop DHIS2 trackers, beginning with the malaria pre-elimination tracker (UNDP, 2020). In an effort to support continuous capacity development, UNDP continues to organise training and learning exchanges with the University of Oslo, the owners and developers of DHIS.

The ePMS is another nation-wide HIS that is used to track and monitor HIV patients taking antiretroviral therapy (ART). With the increase in the number of patients accessing HIV treatment, the paper-based information system became inadequate and also resulted in massive workload, thus straining the health workers who were already over-burdened. The electronic Patient Management System (ePMS) was introduced in Zimbabwe in 2013 to "collect and manage HIV and TB data at the patient level, with the ultimate aim of phasing out paper registers throughout the country" (UNDP, 2014:5). Using lessons learnt from Namibia, Zambia and Tanzania, the MoHCC together with its partners namely the UNDP, the National AIDS council, CDC, UNAIDS, WHO and Research Triangle International (RTI) implemented the ePMS. Using ePMS enables information to be viewed by nurse at a clinic or a district health officer includes patient registrations, past medical history, patient follow-up visits, demographic details, laboratory investigations, rates of patient survival as well as prescription and dispensing of drugs (UNDP, 2020). More than 620 sites nationwide have installed the ePMS system since its launch in 2013, making it the most widely-used electronic health information system in Zimbabwe. Major results gained from the use of ePMS include, a more efficient management of HIV and TB patients, resulting in improved patient follow-ups on treatment. There is also enhanced data quality whose use in accurate forecasting and assessments of interventions are promoting effective programming (UNDP, 2014). In terms of capacity building, 4000 health workers and 700 data entry clerks have been trained in ICT skills, by the MoHCC with the assistance of UNDP (UNDP, 2020). Through ePMS the multiple entry of patient information was eliminated. In addition, workload and associated costs of data entry and reporting at the health facility level decreased due to ePMS`s computerised data aggregation and automated data retrieval and analysis. Improved adherence to treatment by patients could be attributed to the ability to track patients and then follow up, using ePMS (UNDP, 2020).

The Public Finance Management System (PFMS), the third system widely implemented in Zimbabwe, processes all receipts and expenditure in all government Ministries, including, the Ministry of Health and Child Care. According to Muzvidzi (2013) the PFMS connects all the Zimbabwean government line Ministries to its parent ministry, the Ministry of Finance and Economic Development and is the sole system that processes all receipts and expenditures.

Muzvidzi (2013) elaborates that the Public Finance Management System (PFMS) is a nationwide government system whose aim is to control, monitor and supervise the management of public funds. It was introduced in 1997 to overcome challenges associated with budget formulation, fragile internal control systems and end user training. Accordingly, the PFMS is therefore used by the Ministry of Health and Child Care for its financial activities including budgeting, receipts and expenditure. Chawurura et al (2019) perceives the PFMS as an e-government initiative in Zimbabwe.

In addition to these three nationwide health information systems, there are also others that are discussed below namely the Laboratory Information Management System (LIMS), Frontline SMS, telehealth and the EHR system. Although the EHR is intended to be a national system, it is discussed here because it is still at a pilot stage and is yet to operate at national scale.

The Frontline SMS system is a Weekly Disease Surveillance System (WDSS) that was introduced in 2011 by the MoHCC with the assistance of their partners, namely, UNDP and the Global Fund together with Health Information Systems Programme – SA (HISPSA) and RTI. The WDSS is mobile phone based and hence an implementation of m-health. Using Frontline SMS surveillance data is captured on mobile phones and automatically sent in real time to a computer database. In this way, surveillance data is transmitted from the health facility point right up to the district, provincial and national levels. UNDP (2020) reported that the introduction of Frontline SMS has greatly improved the timeliness and completeness of surveillance reporting, from weekly reporting transmission rates below 50% in 2010 to a submission rate higher than 95% in 2018, across an average of 1330 health facilities. This number of health facilities is also more than twice the number of facilities that transmitted reports on time prior to the introduction of this mobile phone-based system. According to UNDP (2020), since the integration of the Frontline SMS system into DHIS2 in 2014, the health work force along the decision chain, from service delivery points to policy level, can now access the data required for timely action. The success of the Frontline SMS system is partly due to the critical role played by UNDP in meeting the technological requirements. By 2014 UNDP had distributed more than 1 700 mobile phones to ensure comprehensive coverage across all health facilities, targeting rural facilities without means of communication. Furthermore, the monthly payment of airtime bills for each cell phone by UNDP ensures the uninterrupted connection of users to the system.

The MoHCC in Zimbabwe introduced a national Electronic Health Record (EHR) system, known as “Impilo”, which means “Health” in the local Ndebele language. This is a standards-based patient-centric system that can exchange and make use of health information (interoperable). The National EHR was designed and developed by a purely Zimbabwean development and technical team and was launched in 2016 (Ministry of Health and Child Care, 2020). The EHR system has been piloted only in 2 districts in Zimbabwe namely Uzumba-Maramba-Pfungwe (UMP) and Harare. UMP is one of the districts in the province of Mashonaland Central. The Agile development method is currently in use to continuously develop the EHR system. This approach is characterised by incremental steps and intensive stakeholder support. The EHR system consists of modules for various health care services. Eleven EHR modules had been developed as of 2020, namely; HIV Testing Services (HTS), Maternity, Out-patients Department (OPD), Pharmacy, Option B+, Laboratory, Antenatal care (ANC), TB screening, Expanded Programme on Immunisation (EPI), Post-Natal care (PNC) and Nutrition and growth monitoring (Zimbabwe EHR Roadmap 2020-2023). The system will be scaled-up for more health facilities at local, district, provincial and central levels, further customisation and development of more modules will also be taking place.

Furthermore, there are other e-health systems advances taking place in Zimbabwe that are being implemented by the MoHCC together with its international partners such as Global Fund, World Bank, SolidarMed and CDC. These include e-partograph, the notification of maternal deaths, the piloting of tele-health in Manicaland province, the use of blended learning and the monitoring of clinical mentoring and Zimbabwe's Human Resources Information System (ZHRIS) (Chawurura et al., 2019).

According to Mars (2012), since 1998 health professionals in Zimbabwe, Uganda, Mozambique and South Africa have been receiving online post graduate training in medical informatics and telemedicine through video conferencing, from the University of KwaZulu-Natal in South Africa. This training program was funded by three Fogarty International Centre Training Grants in the International Training for Global Health (ITGH) whose aim is to develop and improve medical informatics capacity in sub-Saharan Africa (Mars, 2012).

In Zimbabwe, International Non-Governmental Organisations (INGOs) in health typically concentrate on HIV/AIDS as well as Maternal, Neonatal and Child Health plus Adolescents (MNCH+A). Fanta and Pretorius (2018) note that in developing countries, donor-funded e-health systems were designed based on targeted diseases such as HIV/AIDS, TB and malaria depending on the information needs of the donors. This means different disease-specific information systems are implemented within a health facility but devoid of communicating with each other, thus the interoperability problem arises. Eventually, "this places the data collection burden on healthcare workers, and causes a dichotomy between the healthcare data team and health systems managers" (Fanta and Pretorius, 2018:133). This is also common in the Zimbabwean e-health discipline.

A small number of these INGOs use dedicated servers resident in Zimbabwe, while the majority of these organisations seem to make use of computing platforms located in other countries, making it difficult for the Government of Zimbabwe to be in control. In addition, e-health experts from the various government ministries are not actively involved in most of the ICT activities that take place, thus inhibiting building and transfer of skills and expertise (Chawurura et al, 2019). In Zimbabwe, e-health initiatives have been introduced in some rural areas. For instance, SolidarMed, a Masvingo-based INGO runs e-health development activities by way of a hackathon every month as well as e-health lab activities every day. These hackathons are characterised by software developers and health professionals collaborating on projects, aiming to develop usable technologies, applications and services (Chawurura et al, 2019). Since 2017 SolidarMed has successfully held 20 hackathons.

According to Moucheraud et al (2017) the United States President's Emergency Plan for AIDS Relief (PEPFAR) via the Centre for Disease Control (CDC) launched the Zimbabwe Human Resources Information System (ZHRIS) in 2009. The ZHRIS is an integrated interoperable system that regularly produces accurate workforce surveillance information that is useful for effective decision-making as well as for enabling the country's health leadership to track their workforce. This ZHRIS system satisfies the Zimbabwe National Health Information Strategy's (2009-2014) need for an integrated system for human resources, administration, logistics, laboratories and transportation (Moucheraud et al., 2017). The Health Informatics Training and Research Advancement Centre (HITRAC) based at the University of Zimbabwe developed and deployed the ZHRIS system. As of 2013 ZHRIS was employed in all the country's provinces. In the long run ZHRIS targets the training, employment and demographics of the country's at least 30 000 health workforce employed in both the government and private institutions.

Thus there are three nation-wide HISs in Zimbabwe, namely DHIS2, ePMS and the PFMS. In addition, to these, the Laboratory Information Management System (LIMS), Frontline SMS, telehealth and the EHR system are also employed, but in selected health facilities. Furthermore, e-partograph, the notification of maternal deaths, the piloting of tele-health in Manicaland province, the use of hybrid learning and the supervising of clinical are additional initiatives that are being implemented by the MoHCC together with its international partners such as Global Fund, World Bank, SolidarMed and CDC.

2.4.4 The sustainability of e-health implementation

According to Moucheraud et al. (2017) sustainability refers to the capability to continue program services after financial, technical and managerial support from external donors comes to an end. Although the use of ICTs in healthcare (e-health) has demonstrated the potential to improve service delivery, it is not clear whether the same benefits would still exist if the same implementations would be scaled up, thus making the sustainability of such initiatives (implementations) uncertain (Leon et al., 2012).

The growing interest for e-health, especially m-health is motivated by the demonstrated benefits of ICTs, the internet, the extensive availability of mobile phones and the reasonably low levels of literacy that is needed for one to use those (Leon et al., 2012). Benefits of e-health focus on rapid collection, transformation, transmission and storage of data which enable timely access to data, real time monitoring of collected data, complex data analytics and automated reporting (Leon et al., 2012). Regardless of the extensive application of ICT in health, a number of reviews have recently highlighted gaps in evidence on the effect of e-health when implemented on a large scale. A major drawback in these efforts is the small scale of e-health projects. Furthermore, the organisational, social and cultural elements associated with successful e-health, are hardly known or documented (Leon et al., 2012).

According to Mechael et al. (2010) most e-health implementations that are succeeding in developing countries are resident in NGOs and are not incorporated into the government's public health services. Integrated systems are complicated by e-health assessments that are inclined to feasibility studies instead of focusing on their sustainability and upscaling, therefore hindering the possibility to make a judgement in terms of benefits (Leon et al 2012). For instance, the evaluation of m-health projects, in most cases, concentrate on intermediate results such as the efficiency of mobile technology over traditional manual (pen and paper) methods and improved information management processes, instead of long term issues such as health systems strengthening and improvement of service delivery processes hence sustainability (Leon et al 2012).

In addition, the majority of digital healthcare systems' deployment in developing nations are pilot programs which are managed and financed by INGOs. Most of these e-health systems are disease-specific and not patient-centred. Moreover, data for such programs is usually stored on servers outside the country of implementation, usually the donor's country of origin (Chawurura et. al, 2019). Since the majority of e-health systems are donor-funded and designed to be disease-specific, most of them usually face sustainability challenges (Fanta and Pretorius, 2018). Assessments of m-health projects in developing countries uncovered a number of obstacles towards the scaling up of such initiatives. According to Leon et al (2012) some of these hindrances include sustainable funding, integrating new technology with existing information systems and proper leadership.

Contemporary concerns about e-health are centred on the scaling up of e-health (pilot) projects and ensuring sustainability. Fanta and Pretorius (2018) posit that e-health projects tend to suffer from "pilotitis" which is "frequently used by donors and governments to express dissatisfaction with the failure to take the implementation of eHealth projects beyond the pilot stage in low and middle-income countries" (Fanta and Pretorius, 2018:133). It has been reported that the pilot stage of most e-health projects does not take into account critical factors such as social and organisational issues, but only concentrate on the technical viability of the project, yet these factors also determine the success of electronic health projects. A pilot project that is successful in one context is likely to exhibit dissimilar results in a different context because of dissimilar influences related to funding, technology and the political environment (Franz-Vasdeki, Pratt, Newsome & Germann, 2015). Franz-Vasdeki et al (2015) highlight the importance of incorporating isolated e-health projects in various contexts in order to facilitate their sustainable deployment. There are five fundamental elements to take into consideration to ensure that e-health pilot projects can be scaled up effectively. According to Franz-Vasdeki et al (2015:36) these are: "improved evidence, technological integration and interoperability, sustainable financing, global and national policies that support the use of technology and a health community that can design and deploy technologies for health".

Despite the typical characteristics of e-health pilot projects (failure to scale up), Uganda's mTrac exemplifies a digital health project which pulled through "pilotitis". The mTrac project is an example of an m-health system that was successfully scaled up to national level in 2011. Because of this, in 2013, the African Development Bank ranked mTrac as one of the top 10 e-health projects (Franz-Vasdeki et al 2015). It was designed to be a data collection and auditing tool whose focus is on the "collection, verification, accountability and analysis of data generated at community and health facility levels" (Franz-Vasdeki et al 2015:36). Interoperability with other existing e-health systems such as DHIS2 and manual (paper) systems for reporting, were the major design principles (Franz-Vasdeki et al (2015). The strength of mTrack was good technical support, despite infrastructure challenges such as internet connectivity constraints and intermittent electrical power outages (Fanta and Pretorius, 2018). Through Uganda's mTrac, it was reported that the strength of the underlying health system is vital in determining the success of an electronic health system. According to Fanta and Pretorius (2018) the successful scale up of mTrac was due to the following factors: the system design paid attention to interoperability; the underlying technology was in line with the prevailing national structure, policies and institutions; the harmonisation of various stakeholders and reducing government investment in order to achieve sustainability.

With regards to accomplishing sustainable e-health implementations, stakeholders need to take note of certain hindrances. These include sustainable funding, proper leadership and integrating new technology with existing information systems. In addition, it is important to consider that in addition to technical viability, social and organisational factors play a critical role towards accomplishing sustainable e-health implementations.

This section discussed several issues under general e-health systems. First is a discussion of (the) WHO's global diffusion of e-health based on eight thematic areas (e-health foundations, legal framework for e-health, m-health, electronic health records, telehealth, social media, e-learning in health sciences and big data); second is an overview of e-health systems implementation in Zimbabwe and third a discussion of the sustainability of e-health implementations.

2.5 Interoperability

Interoperability is a concept that was introduced decades ago and has been used in various ways since then. There are also numerous definitions for interoperability that have been noted in literature. Interoperability has been the subject of interest in a variety of application areas. The military domain was seemingly the first to refer to interoperability in the 1970s. Over time, interoperability was used in ICTs application and of late it has been applied in other fields such as e-health, public services and enterprise interaction (Öhlund, 2017). According to IEEE (1990), interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

2.5.1 E-health interoperability

According to Mansoor and Majeed (2010), e-health interoperability refers to communicating and exchanging patient data accurately, securely, effectively and consistently by different information systems, software applications and networks in such a way that clinical or operational purposes and meaning of the data are preserved and unaltered. Adebesin et al. (2013:56) contend that interoperability in healthcare refers to "the ability of health information systems to work together within and across organizational boundaries in order to advance the health status of and the effective delivery of healthcare for individuals and communities". Thus the ultimate goal of e-health interoperability is to provide improved healthcare.

2.5.2 Initiatives for e-health inter-operability

Dogac (2012) notes that there are several successful e-health inter-operability initiatives in Europe, such as Turkey`s National Health Information System (NHIS) or (NHIS-T); the European Patients Smart Open Services (epSOS) initiative for sharing Electronic Health Records (EHR) and e-Prescriptions. According to Kose et al. (2008) the launch of the Health Transformation Programme marked the beginning of the initiative for Turkey's National Health Information System (NHIS) or (NHIS-T). The aim of the NHIS is to provide a nation-wide infrastructure that can efficiently share electronic health records. The system also gathers healthcare data from all health centres (clinics, laboratory systems, hospitals and family medical centres) in Turkey and send it to the Ministry of Health servers in Ankara. The infrastructure for messaging is centred on HL7 v3 while the transportation and communication service are provided by HL7 Web service profiles.

The messaging infrastructure is based on HL7 v3 while the communication and transportation service are provided by HL7 Web service profile. The clinical document format is HL7 v3 CDA Release2 while the Web Services (WS) security configurations were applied to offer shared categorisation systems that can be used by all stakeholders in healthcare. The Department of Information Processing in the Ministry of Health came up with the Health Coding Reference Server (HCRS) which summarises all the national and international coding methods that are used in Turkey. In addition, the National Health Data Dictionary (NHDD) which contains 261 data elements were developed to enable healthcare provider services and partners to have a common understanding of data and enable them to use it for identical proposes.

Furthermore, Minimum Health Data Sets (MHDS) which currently contain 46 elements, were formed from the NHDD to facilitate data collection. Lastly the Doctor Data Bank (DDB) serves to provide the identity and specialisation of healthcare professionals. The NHIS is based on the e-health network known as “Saglik-Net” which connects the three major components, first the (NHDD) and the (MHDS) Server, second the Health Coding Reference Server and thirdly the digital security procedures.

The European Patients Smart Open Services (epSOS) is another example of an initiative for inter-operability in e-health. epSOS is a project for e-health interoperability co-established by the European Commission together with its associates. This epSOS initiative focused on EHRs (availability of healthcare data in the patient’s country of residence while getting treatment in a foreign country) and e-prescription (ability to access someone’s e-prescription in their country of residence) for cross border patients. The epSOS project was a five-and half-year pilot project that ran from 01 July 2008 to 31 December 2013. The objective of epSOS is to advance the healthcare services given to individuals when they are out of country through offering healthcare professionals the essential patient data in a protected electronic structure. Specifically, epSOS strives to deliver unified medical services to citizens of Europe by developing and accessing a health service infrastructure.

The aim of the pilot is to demonstrate that it is feasible for any member state that already provides these e-health services to its residents, to create the conditions that will allow it to also offer the same services to them when they travel abroad to other member states taking part in the epSOS pilot project (European Union, 2013). Results of this pilot program could not be accessed at the time of writing.

2.5.3 Benefits of e-health interoperability

E-health interoperability has several benefits for various stakeholders. Luna, Campos & Otero (2019) highlight some of the benefits of interoperability in healthcare for different stakeholders such as patients, the government and organisations.

From the point of view of a patient, interoperability increases the safety of a patient due to increased accessibility and availability of one’s medical information. GSMA (2016) concur that faster and easier access to patients’ clinical data is one of the benefits of e-health interoperability. Instant access to patient data enables medical practitioners to quickly diagnose patients hence promoting continuity of care (GSMA, 2016). Patients can also access their medical records via patient portals. Furthermore, patients using the health system’s different services, can easily move between private and public healthcare facilities as well as request for a second opinion (Luna et al., 2019).

Governments benefit from e-health interoperability reducing potential for errors and incomplete data (needed for reporting, forecasting and budgeting) because of integrated systems. Interoperable health systems make it easy for governments and health departments to report on issues like pathology and disease incidence, community morbidity, disease reporting and disaster response. In addition, shared information would be easily accessible for referrals, consultations and availability of medical equipment. Luna et al. (2019) reported that in 2017, Canada's interconnected healthcare systems benefited by saving the health system $19.5 million because of reduced imaging duplications, and C$9 million through reduced duplications of lab tests. On the same note of reducing errors, GSMA (2016) agrees that interoperable HISs allow data to be shared thereby eradicating the need for re-entering data into the system each time.

From an organisational point of view, the benefit of interoperable health systems is derived through accomplishing interoperability between legacy systems and new business information systems using different programming languages, data models, communication protocols and interfaces since there is a need to share and use the same information across multiple platforms. This integration eliminates the need to enter information twice thereby reducing the probability of data upload errors (Luna et al, 2019). In agreement GSMA (2016) posit that interoperable systems lead to a reduction of administrative costs emanating from reduced manual data capture.

According to GSMA (2016) another benefit to organisations is that more interoperable health systems open up opportunities for new vendors to penetrate the market, thus promoting competition. This usually leads to more choices for both healthcare providers and consumers, like what happened in the mobile industry from the time standards for network interoperability were introduced.

On the contrary, the lack of interoperability in e-health has several consequences. According to ITU (2017) non-interoperable e-health systems lead to: burden on health workers and administrators, wastage of digital health resources, poor data management, constraints to innovation and distraction from building national systems and infrastructure and absence of system-wide ICT impacts.

Burden on health workers and administrators is one effect resulting from using health systems that do not interoperate. The use of non-interoperable health systems by health workers and administrators adds excessive burden to their work. For example, a health worker may be required to log in to a number of systems using different authentication methods and user identification methods. This leads to confusion, increased data entry errors and disturbs the health worker from providing quality service, which is their core business (ITU, 2017). The Zimbabwe Electronic Health Record system (EHR) Roadmap (2020-2023) concurs that in Zimbabwe, nursing staff are the primary data collectors at health facilities and are therefore required to enter information on numerous reporting forms, tally sheets and registers in combination with attending to patients. As a result, these nurses spend more time making entries to forms and registers instead of giving quality care to patients.

The use of health systems that are not interconnected also leads to a wastage of digital health resources. According to ITU (2017), public funds including grants from aid organisations are in most cases used for paying and supporting different e-health projects that often have overlapping and non-compatible functionalities. In addition, there are costs associated with legacy systems that must be integrated, thus needing money for re-designing and reengineering purposes. However, in most cases, these would be vertical projects, thus resulting in time and effort duplication.

Poor data management is another consequence emanating from health systems that do not interoperate. Access to information is often limited to the system or application that captured it, hence making it difficult to share and consolidate data. In this case, inconsistencies in coding and data entry reduces the data quality, hence creating opportunity for errors. Consequently, these challenges potentially cause health workers to make poor decisions, thus negatively affecting patient safety and public health (ITU, 2017). In agreement, Li, Clarke, Neves, Ashrafian & Darzi (2021) note that a lack of interoperability in e-health results in the disintegration and fragmentation of patient information, thus patient data cannot be shared. According to ITU (2017) a lack of interoperability in healthcare also restricts digital health innovations among software developers. Owing to the siloed design of electronic HIS in most countries, developers dedicate time and resources to reproducing code and technologies that already exist in numerous digital health applications, hence hindering innovations in e-health systems.

Dwivedi et al. (2021) note that, in Tanzania the low levels of e-health systems interoperability, reduced the accessibility and compatibility of health information. Furthermore, the sharing of data across the various sources residing in councils for professionals, universities, organisations that don't belong to the government, the health ministry, the finance ministry and the education ministry, was also limited. This resulted in serious data gaps as well as missed chances to engage in new and promising tools, approaches and practices.

2.5.4 Relating e-health interoperability to the research objectives

This section discusses the link between interoperability and the study's objectives. The first objective was: to determine the current status of e-health implementation in Zimbabwe. There exists a positive correlation between e-health implementation and e-health interoperability. Where the level of e-health implementation is high, the e-health interoperability status is also likely to be high. In other words, e-health implementation is the foundation for e-health interoperability, hence the need to first ascertain the status of e-health implementation first and foremost.

The second objective was: to determine the current status of e-health interoperability in Zimbabwe. This objective was at the centre of this study. Interoperability pointers such as use of interoperability standards, the number of e-health systems that can exchange and share, availability of trained e-health experts could be used to determine the status of interoperability in healthcare. Outcomes of the e-health interoperability status in Zimbabwe would inform the manner in which interoperability would be implemented.

Objective three was stated as: to determine the barriers in the implementation of e-health interoperability. Knowledge of the obstacles to interoperability in e-health enables the researcher to find appropriate and valid solutions to each of them. It is only after the obstructions have been identified and solved that interoperability can be executed.

The fourth objective was: To determine the enablers in the implementation of e-health interoperability in a developing country context. Enablers refer to the conditions or circumstances that facilitate interoperability to take place. Identifying these enablers promotes the smooth flow of interoperability in e-health.

To identify consequences of a lack of interoperability in a developing country context was the fifth objective of this study. The effects of a lack of interoperability can act as motivation to implement interoperability in e-health. If lack of interoperability has negative impacts on patients, health professionals and the government for instance, then this drives the responsible stakeholders to advocate for e-health interoperability.

The sixth and last objective was: To develop a framework for implementing e-health interoperability in a developing country context. This was the aim of the study. Since the level of e-health interoperability is generally low in developing countries, data collected using objectives 1-5 was intended to inform the development of this particular framework.

This section articulated the relationship between the study's objectives and the concept of e-health interoperability.

2.6 Introduction to standards

Despite the prospective benefits of e-health to patients, care givers and other stakeholders, it appears the rate of e-health implementation is still slow, especially in developing countries. According to ITU (2011) cited in Adebesin et al (2013), one of the obstacles towards realising the benefits of e-health is the difficulty of sharing medical information, which by its nature is complex. Standards drive interoperability and are critical in pursuit of e-health interoperability. Adebesin et al (2013:56) concurs that “standardisation is pertinent in the accomplishment of interoperability”. The same sentiments were echoed by Iroju, Soriyan, Gambo & Olaleke (2013:267) that, “Thus, the pursuit of high standards of patient care and safety is futile in the absence of uniformity or standardization of the basic means of communication”. Standards are basically specifications that allow health-related information systems developed by different providers, to interoperate. According to DeNardis (2012) standards are blue prints used by technology developers for creating products that would essentially, be compatible with other products adhering to the same standard. ISO (2004) cited in Adebesin (2013:58) defines standards as “a document established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context”. Thus, in other words, a standard is neither hardware nor software, but an agreed way of doing something, hence, a blue print. Despite the noble role of standardisation in e-health interoperability, there are barriers towards its adoption and use. According to Adebesin et al (2013), the availability of a wide variety of standards that are in most cases overlapping, contradicting and/or competing, is one challenge hindering e-health standardisation. An additional challenge noted by DeNardis (2012) is that a number of these e-health standards are neither interoperable with each other nor directly coordinated with each other at an institutional level. Hence, the subject of standards in e-health interoperability deserves attention and continuous research in order for e-health interoperability to be realised.

2.6.1 Standards Development Organisations (SDOs)

Organisations that develop standards are known as Standards Development Organisations (SDOs). They are responsible for developing standards which can be proprietary or open source. Proprietary standards are those that are developed by profit-driven organisations, are meant for private use and are usually copyrighted and their specifications are usually not disclosed. On the other hand, open standards can be developed by profit organisations as well as non-profit organisations. Open standards can be used by anyone interested in them and their specifications are typically publicly available either for entirely no charge or are purchased at a nominal fee (Adebesin et al., 2013). In most cases technical committees (TC) are set up within these SDOs for the actual development of standards (Luna, Campos & Otero, 2019). Examples of technical teams are ISO’s Technical Committee 215 (TC215) for Health Informatics also known as ISO/TC215, and the CEN”s Technical Committee 251 also known as CEN/TC251.

The sections that follow are a discussion on some of those SDOs that are developing standards to promote interoperability, namely; International Organisations for Standardisation (ISO), Health Level Seven (HL7), World Health Organisation (WHO), Integrating the Healthcare Enterprise (IHE), European Committee for Standardisation and the Regenstrief Institute.

2.6.1.1 International Organisation for Standardisation (ISO)

ISO is the largest standards development organisation in the world and has developed international standards in a number of domains. Among other things, ISO, through its standards aims to enable interoperability between and among autonomous systems, promote compatibility and minimise duplication (Luna et al, 2019). For ISO, technical committees, which consist of national member bodies are responsible for developing standards. For instance, ISO/TC215 is ISO's health informatics technical committee for developing e-health standards. According to Adebesin et al (2013), ISO has three types of affiliation or membership namely, full membership, correspondent and subscriber membership. The membership type of a country also determines its capacity to influence the type of standards developed. According to Luna et al (2019) ISO has published 116 standards, to date. These include the Health Informatics-Service Architecture (ISO 12967:2009) and the Identification of Subjects of Health Care (ISO/TS22220:2011). When developing standards, ISO collaborates with other SDOs like HL7 and CEN for ISO accreditation, thus enabling the standards to be adopted internationally.

2.6.1.2 World Health Organisation (WHO)

The World Health Organisation (WHO) is in charge of publishing and maintaining the International Classification of Diseases (ICD) standard used for categorising medical conditions, sicknesses and causes of death. In collaboration with the International Health Terminology Standards Development Organization (IHTSDO), WHO facilitates the cross-mapping of the Systematised Nomenclature of Medicine Clinical Terms (SNOMED-CT) terminologies with ICD codes (Adebesin et al, 2013).

2.6.1.3 Health Level Seven (HL7)

Health Level Seven (HL7) is an international American-based not-for-profit organisation that is approved by the National Standards Institute (ANSI) and was established in 1987. HL7 is devoted to the development of messaging standards for e-health interoperability. These standards are also responsible for exchanging, storing and using electronic health information as well as integrating clinical and administrative health-related data among disparate various healthcare applications. According to DeNardis (2012) HL7 provides application layer standards, hence the "7" in HL7 similarly refers to the application layer, that is layer 7, of the ISO/ITU Open Systems Interchange (OSI) reference model for describing technical standards. Furthermore, HL7, therefore denotes the standards development organisation name as well as the HL7 group of standards. According to the Health Information and Quality Authority (2013) standards provided by HL7 comprise HL7 version 2.x and beyond (v2.x), HL7 version 3 (v3) and beyond, Clinical Document Architecture (CDA), Clinical Context Object Workgroup (CCOW) and the Arden syntax. Luna et al (2019) notes that, in terms of affiliation, HL7 is composed of more than 2300 members, of which 500 are corporations. Most of these members are either involved in providing health information systems and products or are involved in health delivery or technology. Technology companies such as IBM, Microsoft, Oracle as well as health providers such as Quest Diagnostics and pharmaceutical companies like Novartis, constitute some of HL7's membership (DeNardis, 2012).

Membership type can be individual or organisational. Helpers in different functional groups develop standards while being supervised by a select committee. HL7 recently launched the Fast Healthcare Interoperability Resource (FHIR), which is a recent interoperability standard that utilises twenty-first century technology to address limitations present in earlier HL7 standards.

2.6.1.4 Integrating the Healthcare Enterprise (IHE)

IHE describes “Integration profiles” based on existing standards for system integration, offering effective interoperability and proficient workflows. IHE assists organisations to attain the level of integration necessary for EHRs (Luna et al, 2019). Luna et al (2019) states that IHE is not a standard, but a recommendation for using existing standards. The IHE’s mission is to improve the way in which healthcare information is exchanged through the specification of standards-based communities (Adebesin et al., 2013).

2.6.1.5 European Committee for Standardisation (CEN)

CEN is a not-for-profit SDO made up of the governmental standards bodies belonging to the 27 countries in the European Union. CEN’s aim is to eliminate obstacles hindering trade and commerce among European nations, through coordinating the European standards development process.

These standards are then implemented by member states as their national standards. CEN and ISO have an agreement whose aim is to inhibit the development of parallel or conflicting standards. Through this agreement, a CEN standard can be adopted as an ISO standard and an ISO standard can be adopted as a CEN standard (Luna et al, 2019). The technical committee

CEN/TC251 is responsible for developing CEN's e-health standards. This committee aims to promote the implementation of standards that permit European organisations to effectively make use of their investment efforts in medical informatics by way of implementing standards. For instance, CEN/TC251 collaborated with other SDOs such as ISO/TC215.

2.6.1.6 Regenstrief Institute

The Regenstrief Institute is a global medical research organisation that participates in numerous health-related activities. The institute is based at the Indiana University in America. The Regenstrief institute developed the Logical Observation Identifier Names and Codes (LOINC) standard. LOINC is an open, international coding standard meant for reporting laboratory outcomes such as serology, urinalysis and hematology. The clinical observations addressed by LOINC include endoscopy and vital signs input/output.

2.6.1.7 Role of Standards development organisations in Zimbabwe

This section links standards development organisations to the study objectives. Literature suggests that NGOs such as Jembi Health Systems, can play a vital role in promoting implementation of e-health interoperability. These are organisation and stewardship roles that are needed. This study also intended to investigate the dimensions of stewardship and organisational factors that are present in Zimbabwe which could facilitate implementation of e-health interoperability. Work done by standards development organisations impact the status of e-health interoperability in Zimbabwe (objective 2), since standards are at the core of interoperability. In the process, barriers would also be noted (objective 3).

2.7 E-health interoperability standards

Hosseini and Dixon (2016) assert that technical standards must be developed and implemented by the relevant stakeholders in order for interoperability to be accomplished. Interoperability ensures the exchange of data seamlessly. Brooks (2010) concur that data standards are one of the crucial elements for facilitating interoperability. Furthermore, the absence of unchanging standards has been a challenge in health services for a long time. This implies that in order for electronic health interoperability to be accomplished, electronic health standards are mandatory to facilitate communication among heterogeneous health information systems. Healthcare interoperability standards are there to enable HISs to uniformly interconnect irrespective of organisational boundaries as well as regional and state borders. There is a wide range of interoperability standards in use today. These standards can also be classified according to the role(s) they perform in the interoperability process. Currently there is a lack of a common classification method for electronic health interoperability standards. WHO and ITU are some of the organisations that have classifications for e-health standards. After synthesising the different classification systems for e-health standards, Adebesin et al (2013), focusing on standards that promote the interoperability of e-health systems, came up with the following categories for e-health standards: information exchange standards, unique identifiers standards, electronic health record standards, format and content standards, clinical terminology and coding standards as well as privilege management and access control standards, amongst others. This section discusses some of these standards for e-health interoperability.

2.7.1 Health Level 7 version 2.x (HL72.x)

The HL7v2.x family is perhaps amongst one of the commonly implemented communication standards among health information systems for exchanging information related to discharges, transfers, income and laboratory requests among heterogeneous system, to mention a few. Adebesin et al. (2013) posit that admission, discharge and transfer (ADT) data, orders and laboratory tests results are examples of clinical data that can be exchanged using the HL7 standard. Furthermore, the HL7 standard can transmit administrative data such as appointment schedules and billing information. HL7v2.x is characterized by a high degree of adjustability, making it compatible with varied healthcare situations. It supports a wide variety of interfaces implemented in the field of healthcare worldwide and offers a framework for mediating what is not supported by the standard (Adebesin et al, 2013). This makes HL7v2.x the most commonly used standard for health information exchange in the world (Health Information and Quality Authority, 2013).

2.7.2 Health Level 7 version 3 (HL73)

HL7 version 3 standard is HL7 version 2's successor. HL7 version 3 was implemented to deal with the lack of a consistent application data model emanating from the flexibility characteristic of HL7v2 (Adebesin et al, 2013). The Reference Information Model (RIM) forms the basis of HL7 version 3. The Health Information and Quality Authority (2013) posit that the HL7version 3 standard makes use of a model called the RIM as well as a set of rules and procedures known as the HL7 Development Framework (HDF) in order to expand the detail, improve transparency and enforce accuracy the communication requirement.

2.7.3 Fast Healthcare Interoperability Resources (FHIR)

The FHIR standard (pronounced as “fire”) is an interoperability standard for e-health, developed and maintained by the HL7 standards development organisation. Transparency, care coordination and improved clinical decisions are some of the benefits of FHIR. The FHIR standard has minimal-technology specific requirements and is semantic-robust and has the potential to be expanded as needed. Luna et al (2019) notes that the FHIR standard makes use of current web-based technologies such as XML, HTTP and JSON which is in addition to other common tools and formats. Just like the majority of recent applications, the FHIR standard also uses the REST Application Programming Interface (API). In addition, without difficulty the FHIR integrates with mobile devices, web applications and data exchange with any e-health system using modular components (Luna et al, 2019). This standard addresses messaging and document standards as well as bulk data sending.

2.7.4 Clinical Document Architecture (CDA)

The Clinical document Architecture (CDA) is an e-health interoperability standard that stipulates the format and meaning of medical reports such as release notes, laboratory investigation reports, clinical summaries and radiology investigation reports (Adebesin et al., 2013). Dolin et al (2006) cites in Luna et al (2019), that the Clinical Document Architecture (CDA) which is based on HL7 V3 is another fundamental standard developed by HL7. Dolin et al (2006) furthermore notes that, the CDA standards stipulates the structure and semantics of clinical documents such as diagnoses, referrals and medical processes. CDA was developed to ensure the human readability and computer readability of healthcare information. The conditions for CDA document usage include persistence, potential for authentication, wholeness, context, stewardship and human readability (Health Information and Quality Authority, 2013). The basis for using CDA-based documents is important when deciding whether to transmit medical information using a message or a document. The Health Information and Quality Authority (2013) stipulates that CDA is designed to be independent of the messaging or transport mechanisms, thus making it possible to be transmitted across systems regardless of the interoperability protocol being used. This would include all those messaging protocols stipulated by HL7. The CDA specification outlines procedures and recommendations for transmitting CDA in version v2.x and version v3 messages of the HL7 standard.

2.7.5 International Classification of Diseases (ICD)

The International Classification of Diseases (ICD) “is an international coding system of diseases, signs, symptoms, abnormal findings, complaints, social circumstances, underlying causes of death and external causes of injury or diseases” (Health Info and Quality authority 2013:20). ICD enables the collation of important health measurements such as morbidity and mortality plus medical care reimbursement. ICD is referred to as the standard instrument for identifying diseases and managing healthcare issues that include analysing a community’s general health status. The use of standard codes for disease circumstances is what basically promotes interoperability in healthcare. The World Health Organisation (WHO) develops and maintains the ICD standard.

2.7.6 GuideLine for Interchange Format (GLIF)

The Guideline for Interchange Format (GLIF) blueprint is composed of the GLIF model and the GLIF syntax. The former (GLIF model) comprises an object-oriented illustration composed of a group of categories for guideline objects, characteristics for those objects and the data types for each characteristic values. The goal of GLIF is to facilitate the exchange and sharing of clinical practice guidelines among health providers and their systems (Ohno-Machado, Gennari, Murphy, Jain, Tu, Oliver, Pattison-Gordon, Greenes, Shortliffe and Barnett, 1998). GLIF3 is the current version in use after GLIF2. GLIF3 allows the encoding of a guideline at three levels: a conceptual flowchart, a computable specification and an implementable specification (Boxwala, Peleg, Tu, Ogunyemi, Zeng, Wang, Patel, Greenes and Shortliffe, 2004). Thus, the GLIF3 model is composed of classes, their attributes and the relationships among these classes, all of which are vital for modelling practice guidelines.

2.7.7 Arden Syntax

Arden Syntax is a standard language for representing and interchanging clinical information through the use of Medical Logic Modules (MLMs). An "if-then" rule together with a systematic conventionalism constitutes a Medical Logic Module. The Arden syntax which is maintained by the HL7 organisation was initially launched in 1989. The first implementation of Arden Syntax was in 1992 by the American Society for Testing and Materials (ASTM). The Arden syntax enables knowledge portability while MLMs developed in one environment cannot be easily embedded within another. The majority of commercial applications integrating MLMs are usually developed by individual vendors, mostly for use within their own environments (Health Information and Quality Authority 2013).

2.7.8 E-health interoperability standards and technology

Standards are key for the successful implementation of e-health. E-health interoperability standards fall under the technology dimension. In this regard, this study investigated technology factors impacting e-health interoperability implementation in developing countries, specifically in Zimbabwe. Leon et al (2012) assert that the technological challenges for implementing interoperability in e-health include: the complexity of ensuring interoperability and integration of information systems, securing the privacy of health information as well as poor ICT infrastructure. The interoperability of information systems guarantees smooth communication across technological and information platforms including a smooth integration with existing work practices. This can only be achieved through the use of interoperability standards. Standards that are required for interoperable systems can be developed through consensus among various stakeholders such as health ministries, clinical staff, patients and digital providers (Leon et al, 2012). This section is linked to the technological dimension among the objectives. The need for standards to facilitate interoperability in healthcare is universal. It is a requirement for both developed and developing countries.

2.8 Health Information Exchange (HIE)

A Health Information Exchange (HIE) enables healthcare professional such as doctors, nurses and pharmacists to securely share a patient's health information electronically. In accordance with the Health Information Systems Society (HIMSS), health information exchange promotes interoperability. Examples of HIE include the Open Health Information Exchange (OpenHIE) and the Asian eHealth Information Network (AeHIN).

2.8.1 OpenHIE

The Open Health Information Exchange (OpenHIE) is a community of practice involving individuals, organisations, donors and countries in promoting the sharing of healthcare data among different software applications (Seebregts et al., n.d.). The OpenHIE strives to use software that is based on standards in an attempt to promote the interchange of patient data. Jembi Health Systems, a non-profit making organisation is one of the creators and leaders of the OpenHIE initiative. Seebregts et al. (n.d.) note Jembi is in control of the interoperability layer community and the shared health record community of the OpenHIE. The OpenHIE community was born to provide countries a structure that can assist them to solve issues pertaining to health information architectures of their own countries, through re-usable technologies and extensive experience. The OpenHIE "community of communities" was formally established in 2013. Currently, OpenHIE`s community processes, reference technologies and approaches are being implemented in several countries such as Tanzania, South Africa, Uganda, Bangladesh, Philippines and Sierra Leone.

The Open Health Information Exchange (OpenHIE) is a technical club or learning network that is dedicated to building interoperable open data standards so that Health Information Systems (HIS) can have interoperability. OpenHIE promotes collaborative development of openly accessible and usable standards that are useful in improving healthcare services in developing communities and countries to build standards-based far-reaching health information systems. The overall objective of OpenHIE is to increase the interoperability of HISs. OpenHIE is composed of several organisations including; Jembi Health Systems, Apelon, Intrahealth, Regenstrief, Path and Centre for Disease Control and Prevention (CDC). The OpenHIE has developed the following reference tools or implementations; open source Human Resources Information Solution (iHRIS) management, District Health Information System Version 2 (DHIS2), Distributed Terminology System (DTS) Version 4, Open Medical Record System (OpenMRS) and Open Enterprise Master Patient Index (OpenEMPI) and the Open Health Information Mediator (OpenHIM), to mention a few.

The OpenHIE community also offers assistance to implementers of the OpenHIE platform. The OpenHIE community supports interoperability of health data through building a re-usable architectural structure based on a service-oriented methodology that strengthens standards for health information. OpenHIE has three broad functions which are; facilitating wide-range interoperability of health information, giving standards-bases methodologies for free and reinforcing one another's necessities by way of fellow technical support communities. These are achieved through the following services: architectural patterns, implementations, guidelines, ecosystems, standards, open-source tools and requirements. The OpenHIE architecture reinforces interoperability through constructing a framework that greatly influences standards of health information and supports individual components interchangeability.

<u>OpenHIE architecture</u>

According to OpenHIE (2020) the OpenHIE architecture represents the key architectural components in a health information exchange. There are also reference technologies/tools associated with the OpenHIE. These are examples of software that support the OpenHIE architecture and OpenHIE workflows. The diagram (Figure 2.2) that follows is a top-level logical general idea (or conceptual diagram) of the OpenHIE architecture.

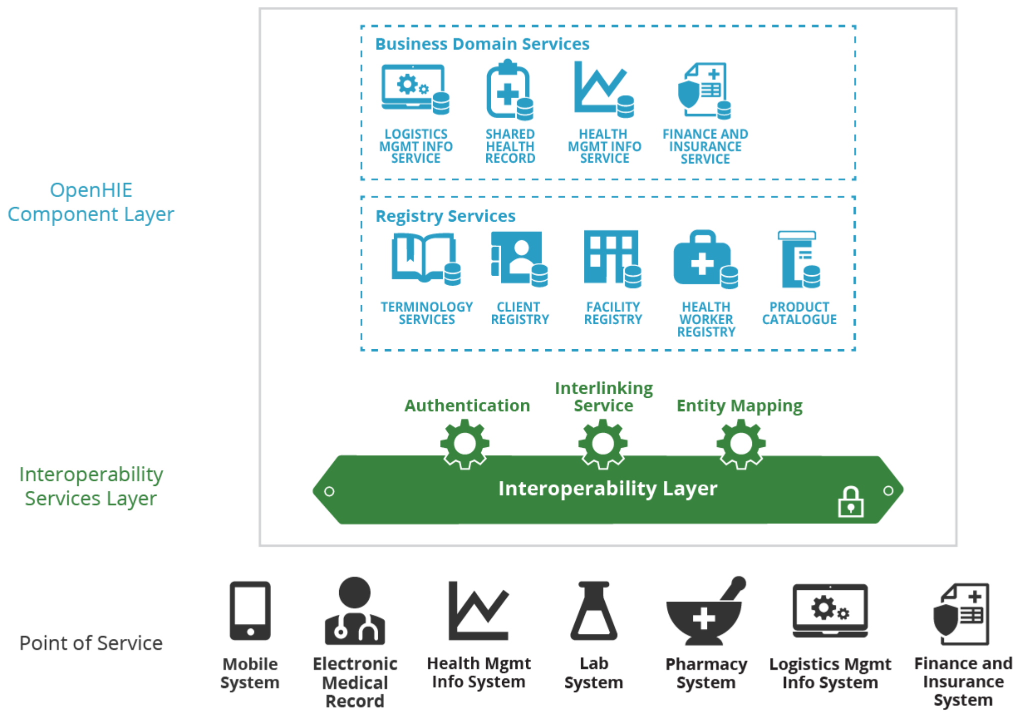

Figure 2.2: OpenHIE Architecture diagram

Source: OpenHIE (2020)

The outer grey box represents the OpenHIE elements that are a part of a shared infrastructure that can be supported at organisational, national or project level (OpenHIE, 2020). Outside and below the grey box are the point of service applications that represent systems or applications used at facility level such as Pharmacy systems used by pharmacists for dispensing drugs and m-health applications used by community health workers and clinicians to access a patient's medical information (OpenHIE, 2020).

The Business Domain Services consists of components that are meant to support business-related health systems. Logistics Management Information Service (LMIS), Shared Health Record, Health management Information Service as well as Finance and Insurance services belong to this category. LMIS ideally facilitates the supply, distribution and movement of health-related commodities within the health care ecosystem. OpenLMIS is the reference technology for Logistics Management. A SHR is a compilation of personal patient records whose medical data resides in the HIE. The HMIS keeps aggregate health medical data that has been routinely collected. The HMIS enables the analysis of such data for purposes of enhancing the kind of health services offered. Accordingly the health management information system can be implemented using DHIS2. Finance and Insurance Service enables the management of monetary data within the HIE. This service can be implemented using the open-source Insurance Management System (OpenIMIS).

OpenHIE (2020) stipulates that Registry services house all the registries within the HIE namely: Terminology service, Client registry, Health facility registry, Health worker registry, and Product catalogue. A Terminology service maintains a set of terminology (that uniquely identifies clinical events) using international standards such as SNOMED, ICD10, LOINC, to mention a few. The Distributed Terminology Service version 4 (DTS4) can be used to implement a terminology service. A Client Registry, also known as an Enterprise Master Patient Index (EMPI), maintains the unique identities of people receiving healthcare services within a country. Implementing a client registry can be done using the MEDIC client registry (MEDIC CR) software, Open Enterprise Master Index (Open EMPI) software or the Open Client

Registry (OpenCR) software. A Health Facility registry manages the unique identities of all locations that provide health care services within a country and can be implemented with the Resource map application system. A Health worker registry acts as a principal entity that maintains distinct identifiers of the healthcare workforce in a country. The open source Human Resources Information System (iHRIS) can be used to implement a health worker registry. A product catalogue provides details concerning what the HIE holds. The open-source software, Product Catalogue Management Tool (PCMT) can be used to launch a product catalogue.

The Interoperability service layer consists of the following services, authentication, interlinking service, health interoperability layer and entity matching. The authentication service is responsible for verifying the identification details of software and other requests directing communications to the interoperability layer. The Interlinking Service links healthcare professionals to the required facilities.

A health interoperability layer is responsible for receiving communication from external services such as point of service components and organises how messages are processed by the external systems and the OpenHIE component layer. The Open Health Information Mediator (OpenHIM) can be used for implementing the interoperability layer. At the very bottom of the OpenHIE architecture, is the Point of service which consists of applications used by health care givers, when attending to patients at the point of care. Such applications include lab systems, Finance and Insurance system, EMR, and mobile systems (OpenHIE, 2020).

Rwanda (Crichton, Moodley, Pillay, Gakuba & Seebregts, 2013) and South Africa (Seebregts et al., 2018) are examples of developing countries that have implemented the OpenHIE to facilitate e-health interoperability. In South Africa, the Jembi systems employed the OpenHIE to facilitate interoperability. In Rwanda, the Rwanda HIE is an implementation of the OpenHIE. In Rwanda the OpenHIE facilitated the interoperability between an Electronic Medical Record (EMR) system called OpenMRS and an SMS-oriented software known as RaidSMS that is used for data collection. According to Crichton et al. (2013), Rwanda has a functional Health Information Exchange, the Rwanda Health Information Exchange (RHIE) that enables point of care systems already implemented in Rwanda to connect and interoperate. This development was also known as the Rwanda Health Enterprise Architecture (RHEA) project. Rwanda's health ministry together with its associates (partners) such as Jembi health systems, IntraHealth International, Innovative Support for Emergencies and the Regenstrief Institute, developed the RHIE in 2010. Key components of the RHIE were the national shared health record and an interoperability layer whose role is to make patient medical histories more readily available to healthcare providers so that they can provide better healthcare service (MEASURE, 2020).

In the case of South Africa, the MomConnect program inter-operates with DHIS2. MomConnect is an e-health program that allows pregnant mothers to register for antenatal sessions with a health facility and also enables them to receive stage-based messages related to pregnancy. For instance, the MomConnect program interacts with DHIS2 as it checks whether the health facility chosen by an expecting mother is registered in the Facility Registry of DHIS2. Registration details move into DHIS2 in a standards-compliant format through the OpenHIM, interoperability layer of the OpenHIE. In addition, the MomConnect program via the HIE can add events (e.g. antenatal visits, responses to SMSs received, comments on MomConnect) to the DHIS2 tracker (Seebregts et al., 2018). Jembi Health Systems supports the MomConnect initiative through maintaining and expanding the OpenHIM interoperability layer of the OpenHIE. Jembi does this by linking the front end cell phone registrations by pregnant women, to the back end database for the National Department of Health.

2.8.2 Asian eHealth Information Network (AeHIN)

Tanzania implemented e-health interoperability using a different HIE, one that is based on the Asian eHealth Information Network (AeHIN). Dwivedi et al. (2021) note that in 2019 Tanzania implemented the Tanzania Health Information Exchange (Tz-HIE) which is currently enabling electronic health data exchange among 15 disparate health information systems. This was made possible by the partnership between the Tanzania`s Health Ministry known as the Ministry of Health, Community Development, Gender, Elderly and Children (MOHCDGEC) and the leading Maternal and Child Survival Program (MCSP) of the United States Agency for International Development that developed an interoperable health information system which enables data exchange through an interoperability layer. Tanzania’s HIE architecture was implemented using the Asia eHealth Information Network (AeHIN) and not the OpenHIE as in the case of Rwanda’s HIE. In the case of Tanzania, the interoperability layer was implemented through the HEALTHeLINK tool version 3 as opposed to the OpenHIM used for the OpenHIE architecture, used for Rwanda's HIE. In the process of developing the Tanzania Health Information Exchange (Tz-HIE), the country also adopted the "Mind the GAPS (Governance, Architecture, program management and Standards) framework" which the AeHIN uses to support the usage of ICTs in Asia. In addition, the Tz-HIE also adopted some international data standards for data exchange. These are the ICD10 for standardising data on diseases and deaths as well as the Current Procedure Terminology (CPT) used for coding medical services, examples include CPT codes (10021 – 6990) for surgery and CPT codes (80047-89398) used for pathology and laboratory.

2.8.3 OpenHIE in developing countries

OpenHIE is an important initiative for implementation of e-health interoperability in developing countries. The OpenHIE architecture represents the key architectural components in a health information exchange. It has reference technologies also known as softwares which facilitate interoperability. The OpenHIE also belongs to the technology dimension. Where the OpenHIE architecture is being used there would be a correlation with the status of e-health interoperability. In addition, the OpenHIE represents an enabler for interoperability.

2.9 Interoperability frameworks

The European Commission (2004) cited in Rezaei, Chiew & Lee (2014:200) defines an interoperability framework as "a set of standards and guidelines that describes the way in which organisations have agreed or should agree to interact with each other". An interoperability framework can be viewed as an instrument that facilitates interoperability between objects that work towards a goal. The next section gives a summary of the different interoperability frameworks in literature and then justifies the choice of the adopted Framework for Enterprise Interoperability (FEI).

The interoperability frameworks presented here were identified by conducting a search in relevant published articles on the Scopus and Dimensions databases using the key words “interoperability” and “framework”. In order to complement the search “Google scholar” was also used. Results of the search process returned four interoperability frameworks namely; the Interoperability Development for Enterprise Application and Software (IDEAS) interoperability framework of 2002, the Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications (ATHENA) framework of 2003 and the Framework for Enterprise Interoperability (FEI) of 2010. Descriptions for each of these frameworks are provided below.

2.9.1 DEAS Interoperability Framework

The IDEAS framework was built as a result of the IDEAS scheme whose basis was the European Computer manufacturers Association / National Institute of Standards and Technology (ECMA/NIST) Toaster Model, ISO19101 and on ISO 19119. The ISO models referred to here are both Geographic Information reference models. The IDEAS framework was developed under the Fifth Framework Programme (FP5) and the aim was to address manufacturing and enterprise interoperability issues in Europe (Chen et al 2008a in Rezaei, Chiew and Lee, 2014). Figure 2.3 below illustrates the summarised version of the IDEAS model, whilst Figure 2.4 depicts the detailed (i.e. full version) version of the same IDEAS framework for interoperability.

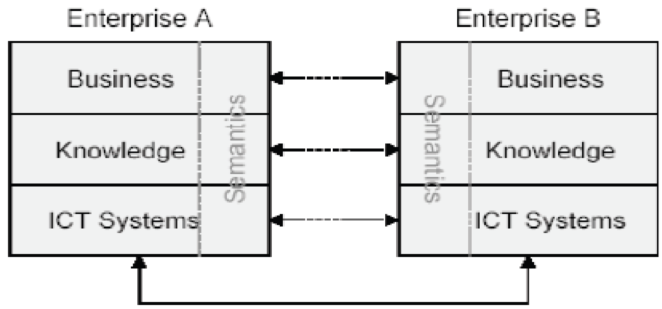

Figure 2.3: Summarised IDEAS interoperability framework

Source: Daclin, Chen & Vallespir (2005)

Figure 2.3 is summarised and only illustrates the interoperations that take place between two enterprises, given as Enterprise A and Enterprise B. ICT systems enable data to be exchanged, while preserving its full meaning (semantics) at both the knowledge level and business level.

Figure 2.4 below shows the full version of the IDEAS interoperability framework and all its components.

	Framework 1st Level	Framework 2nd Level	ONTOLOGY	QUALITY ATTRIBUTES			QUALITY ATTRIBUTES		
			Semantics	Security	Scalability	Evolution	Performance	Availability	Portability
ENTERPR. MODEL	Business	Decisional Model							
		Business Model							
		Business Processes							
	Knowledge	Organisation Roles							
		Skills Competencies							
		Knowledge Assets							
ARCHITECT PLATFORM	Application	Solution Management							
		Workplace Interaction							
		Application Logic							
		Process Logic							
	Data	Product Data							
		Process Data							
		Knowledge Data							
		Commerce Data							
	Communicat ion								

Figure 2.4: Detailed IDEAS interoperability framework

Source: Rezai et al. (2014)

The detailed version of the IDEAS interoperability model shows all the layers of an enterprise that must interact for interoperability to take place between enterprises. On the business layer, business procedures and practices must interoperate. At the knowledge level, employee responsibilities, expertise and proficiencies must interoperate. Software, data and messaging mechanisms must interoperate at the ICT level.

Chen and Doumeingts (2004) stipulate that the three research domains required for building interoperability among enterprise applications are enterprise modelling, architecture platform and ontologies. The purpose of enterprise modelling is to define when an application operates and the part of the enterprise modelling needed for communication. It also describes the data and processes that should operate with other applications.

The architecture or platform comprises a set of technology-based services or functions which are responsible for the implementation and execution of enterprise applications. Ontologies address the semantic component of interoperability by describing the meaning of the terms used in a particular business area (Chen & Doumeingts, 2004).

The IDEAS framework advocates that interoperability should be accomplished at distinct organisational layers namely the data level, the business level, the application level, communication level and the knowledge level. The IDEAS framework is composed of two major components, namely the Enterprise model and the Architect platform. Each of these two major components are expressed in terms of four dimensions which are framework first level, framework second level, ontology (semantics) and quality attributes (security, scalability and evolution). These four dimensions cut across the two major components which are Enterprise model and Architect platform.

Enterprise model

The Enterprise model consists of the Business level and Knowledge level under the Framework First level dimension.

Business level

This level addresses all the aspects associated with management as well as the enterprise' organisation. The Business level also details how the enterprise is organised and how relationships with personnel and other stakeholders are managed. In other words, the Business level of the IDEAS framework relates to organisational interoperability. The business level is composed of business processes, the business model and the decisional model which fall under the second level of the IDEAS framework. The business processes are actions that aim to deliver value to customers. The business model defines the commercial relations between enterprises and how they provide services and/or goods to their market. The decisional model considers the resolutions to be made and how they are made. According to Chen, Doumeingts and Vernadat (2008), interoperability at this level is considered as the organisational and operational capability of an enterprise to accurately cooperate with other enterprises.

Knowledge level

The Knowledge level of the IDEAS framework focuses on the internal aspects of knowledge. This level is responsible for representing, configuring and obtaining individual or shared knowledge of an enterprise. At the Knowledge level the key issues that should be addressed are expertise, harmony and the enterprise assets which are its information and capabilities that are unique from those of other businesses. Furthermore, the Knowledge level constitutes the Knowledge assets, Skills competencies and Organisational roles which are all under the second level of the framework. Figure 3 above depicts that the Business and Knowledge levels constitute the Enterprise model of the IDEAS framework.

Architect platform

The Architect platform consists of the Application, Data and Communication levels which all belong to the first layer of the framework.

Application, Data and Communication levels

The Application level consists of Solution management, Workplace associations, Application reasoning and Process judgment, all belonging to the first level of the framework. Process logic refers to the sequence of steps that an application follows. Application logic are the calculations and computations performed by the enterprise system(s) to achieve business outcomes. Workplace interactions describe the way humans interact with the system through input, navigation and output. Lastly, solution management covers the procedures and equipment needed by the enterprise systems' administrators, such as monitoring and simulation tools (Bourrières, 2006; Chen et al., 2008a; Zwegers, 2003 in Rezaei et al., 2014). The data level comprises commerce data, knowledge data, process data and product data. Enabling enterprises to function, making resolutions and interchanging messages are the general responsibilities of the Data, Communication and Application levels of the IDEAS framework.

Chen, Doumeingts & Vernadat (2008) state that the chief drawback of the IDEAS interoperability framework is that it is not based on the interoperability domain itself, instead it is based on the three related domains for research which are enterprise modelling, architecture and platform as well as ontology. Rezaei et al (2014) concur that the focus of the IDEAS framework is on three related research fields namely; enterprise modelling, architecture and ontology. Thus, it can be concluded that the IDEAS framework is not suited to explain information systems interoperability (including e-health interoperability) but more geared towards the fields of ontology, enterprise modelling and architecture. Thus, this disqualified the IDEAS framework from being adopted as the underlying theory for this research study because the emphasis of this study is on e-health interoperability.

2.9.2 Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications (ATHENA) interoperability framework

The ATHENA framework was developed in 2003 as a way of presenting outcomes from the ATHENA Integrated Project (IP). Facilitating interoperability using reference architectures, methods and infrastructure components in Europe, is the objective of the ATHENA (IP). The European Commission under Framework Programme 6 (FP6) which deals with the interoperations of software applications funded this project, the ATENA IP. ATHENA assumes a general perspective on interoperability for analysing and understanding business essentials and the technical needs required to solve the interoperability problem. ATHENA is based on the Framework Program 5 (FP5) of the thematic area, network IDEAS.

The ATHENA Interoperability Framework (AIF) for the interoperability of business software and systems software is meant to provide solution developers and integrators with guidelines on how to use the ATHENA solutions for addressing business needs and technical requirements for interoperability (Berre et al., 2007). The AIF adopts a holistic perspective centered on a multi-disciplinary and model-driven approach towards interoperability with the aim of analysing and understanding the business needs and technical requirements of an enterprise. The AIF emanates from the IDEAS interoperability framework discussed earlier.

The ATHENA Interoperability Framework comprises interoperability methodologies and reference configurations which are different from those of the IDEAS framework. This suggests that the AIF can incorporate outcomes from the following research fields (architectures and platforms, business modeling and ontology) and has the ability to offer a comprehensive perspective for resolving interoperability at the business and levels for ICT.

The structure of the ATHENA Interoperability framework comprises three elements namely; conceptual integration, technical integration and application integration. Conceptual integration is centred on conceptions and ideal relationships while application integration focuses on principles and area models. Application integration also offers recommendations and values used for solving interoperability issues. Finally, technical integration emphasises practical improvement and ICT circumstances and platforms necessary for building and operating systems and applications software for enterprise.

The roots of the ATHENA project reside in a multi-disciplinary methodology that merges the three research domains which support the growth of business software interoperability. Berre et al. (2007) note that these three areas are firstly, enterprise modelling which defines the interoperability requirements and supports solution implementation; secondly, the architectures and platforms which provide implementation frameworks and thirdly, the ontology to identify the interoperability semantics in the enterprise, just like the IDEAS framework.

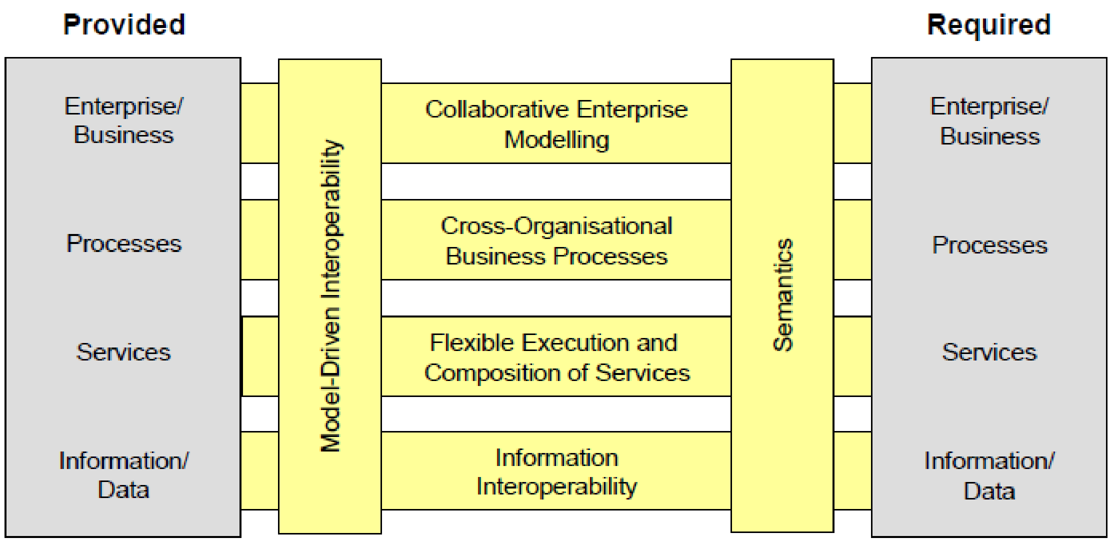

Figure 2.5: The simplified ATHENA Interoperability Framework

Source: Berre et al. (2007)

Figure 2.5 depicts an abridged view of the reference model, showing the artefacts which are "required" and "provided" for two interconnected entities. Based on the AIF, interoperations can happen at any one of the following levels; business level, service level and information level. The ATHENA and IDEAS interoperability frameworks are regarded as complementary

(Chen et al., 2008). Since the ATHENA interoperability framework is based on the IDEAS framework, it also is not appropriate to explain health information systems interoperability (including e-health interoperability) instead it is more geared towards the domains of ontology, enterprise modelling and architecture.

2.9.3 Framework for Enterprise Interoperability (FEI)

The Framework for Enterprise Interoperability (FEI) was developed by Chen and Daclin in 2010. The FEI formed the theoretical framework and the conceptual framework of this research study which are presented in the next chapter.

2.10 Interoperability frameworks and the study objectives

Of the three interoperability frameworks presented, that is, IDEAS, ATHENA and FEI, it is the Framework for Enterprise Interoperability (FEI) that is more aligned to this study's objectives. The IDEAS framework would be more ideal for interoperability in a commercial or business set up. The fundamental concepts for interoperability are not addressed in the IDEAS framework, thus rendering it unsuitable for use in this study. On the other hand, the ATHENA framework was meant for presenting outcomes from the ATHENA Integrated Project (IP). This implies this framework is targeted for a certain project and may not be applicable for universal use (that is, other projects for which it was not intended). The ATHENA framework has been found to work best in research disciplines such as business modelling, architectures and ontology, hence making it unsuitable for this study on e-health interoperability. Furthermore, both the IDEAS and ATHENA frameworks are not aligned to the objectives of this study. The FEI was thus found to be the most appropriate framework to apply in this research study.

2.11 Summary

The chapter discussed literature related to e-health and e-health interoperability. The chapter began by discussing foundations in the health domain namely, health systems, elements of a health system, and the WHO framework for strengthening health systems in developing countries. An overview of the health system in Zimbabwe was also discussed, focusing on the country's burden of diseases, its health priorities and successes and challenges. Then followed a discussion on the categories of e-health systems, WHO global diffusion of e-health, an overview of e-health systems implementation in Zimbabwe and e-health sustainability concerns. Standards and their use in e-health interoperability were presented; Implementations of Health Information Exchange (HIE) namely the OpenHIE and AeHIN.

CHAPTER 3

THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Introduction

According to Kivunja (2018:48), a "theoretical framework is an analytical structure you put together or develop to suit your research purposes, which as you know, are to answer your particular research questions and address your stated problem", whilst a theory "is an abstraction, a generalization, and therefore, it is not content, or topic specific". This suggests that a theoretical framework should be grounded on a proven theory. However, Lederman and Lederman (2015:593) postulate that the theoretical framework "may actually be a theory, but not necessarily". This implies that a theoretical framework can be based on other constructs such as frameworks, and not necessarily be based on tried and tested theory. In both cases, the role of a theoretical framework remains the same, which is to provide a roadmap for a research study. Thus, the role of a theoretical framework is to guide the researcher(s) so that they do not diverge from the boundaries of the laid down theories.

3.2 Theoretical Framework

Rezaei and Shams (2008b) cited in Rezaei et al. (2014) contend that interoperability is a multidimensional concept that can be perceived from various viewpoints. Accordingly, a framework is required to bring together these several perceptions, guidelines and approaches which are often dissimilar (Rezaei et al., 2014). Thus an interoperability framework was adopted for solving the e-health interoperability problem in this study. Chen and Daclin's Framework for Enterprise Interoperability (FEI) of 2010 informed the theoretical framework for this study. The choice for this framework was motivated by the fact that it considers the interoperability of an entire organisation as a whole.

Chen and Daclin (2006) developed the Framework for Enterprise Interoperability within the frame of Interoperability Research for Networked Enterprises Applications and Software Network of Excellence (INTEROP NoE) which aims to support scientific development in the domain of enterprise interoperability and software interoperability. This Framework for Enterprise Interoperability (FEI) is composed of three dimensions namely; interoperability barriers, interoperability concerns as well as interoperability approaches. The objective of this interoperability framework (FEI) is to organise issues related to enterprise interoperability. Just like any other framework, FEI does not provide a functional answer to interoperability challenges, but instead aims to provide a way of organising domain-specific issues related to interoperability.

The Framework for Enterprise Interoperability (FEI) postulates that organisations lack interoperability due to the presence of hindrances to interoperability in organisations. These hindrances are inconsistencies of different types and at various levels of an organisation. The inconsistencies impede the sharing of information and inhibit the exchange of services. According to Chen (2006) the FEI was designed based on some of the existing frameworks such as the European Interoperability Framework (EIF) of 2004, IDEAS of 2002 and ATHENA of 2003. The FEI conducts two major activities namely; defining enterprise interoperability using a barrier-driven approach as well as identifying methods of removing these barriers.

Chen and Daclin (2006) further note that a framework denotes a mechanism for organising and grouping objects or entities in a given domain and does not give a functional resolution for solving a business problem. Thus, the objective of the FEI is to organise and put together the ideas related to the research field of enterprise interoperability. The components constituting the FEI are interoperability barriers, interoperability concerns and interoperability approaches.

3.2.1 Interoperability barriers

These refer to interoperability impediments and are classified as; conceptual, technological and organisational.

Technological barriers

Technological barriers pertain to the mismatch or unsuitability of information technologies in terms of architecture, basic framework (infrastructure) and technological platforms. In other words, technological barriers are due to a lack of compatible standards for enabling heterogeneous computing devices to exchange information between at least two systems. Technological barriers include communication-related barriers such as unsuitability of protocols, content barriers such as techniques used to represent information and infrastructure barriers such as the use of incompatible middleware platforms. According to Samardina (2017) hesitancy to undertake a complete renovation of IT systems, integrity of health care data, system reliability and challenges with legacy systems are some examples of technological barriers to interoperability.

Conceptual barriers

Conceptual barriers are about differences in semantics and syntax used in information exchange. Syntactic incompatibility can exist when various systems or people use various configurations or arrangements to denote information. An example would be the UEML initiative (UEML, 2002) that aims at providing a neutral mapping between different enterprise models that were built using different systems. In other words conceptual barriers exist where the same medical notion is represented is two or more forms (Soule, 2020).

Whereas semantic interoperability facilitates the unambiguous understanding of information exchanged between two entities. According to Chen and Daclin (2006) semantic interoperability is regarded as an obstacle to interoperability since the information represented in various models and software do not have precise semantics to support unambiguous meanings of information exchanged. Semantic annotation and reconciliation that use ontologies is the current known technique for solving this problem. Such ontologies define meanings of terms used in a specified business area (Chen & Doumeingts, 2004). Of the three types of interoperability barriers, conceptual barriers constitute the main barriers to interoperability (Chen and Daclin, 2010).

Organisational barriers

These refer to the incompatibility of organisational structures and management techniques used in different enterprises. According to the IDABC cited in Hellman (2010:2) organisational interoperability is characterised by "defining business goals, modelling business processes and bringing about the collaboration of administrations that wish to exchange information and may have different internal structures and processes". In addition, these barriers refer to the definition, authority and people's responsibilities in organisations. The major issues in this regard are to do with authority such as who is authorized to do what and the organizational structure, whether it should be hierarchical or matrix or networked. According to Hellman (2010) barriers to interoperability include low competency, people factor, economic restrictions, invisible best practices and disharmony in legislation. Poor knowledge of business processes denote a hinderance to organisational interoperability. Auschra (2018) posit that different organisational cultures usually create organismal barriers.

3.2.2 Enterprise concerns

These are the organisational viewpoints or stages where interoperability can occur namely; data stage, processes stage, services and business stage. This classification of enterprise concerns is based on the ATHENA Technical framework (Guglielmina et al., 2005 in Chen & Daclin, 2006).

The interoperability of data concerns

The interoperability of data entails sharing information coming from heterogeneous databases which may also be resident on dissimilar machines running for instance, operating systems and database management systems, which are not the same. The interoperability of data can take place when a pair of entities or units interchange two data files for example picture files. However, the interoperability of data can be hindered by technological barriers such as difference in database technologies and coding techniques; conceptual barriers such as difference in semantics or syntax used to represent information and finally organisational barriers like different security policies.

The interoperability of services

Interoperability of services refers to making different applications that were designed and implemented independently, work together. Chen and Daclin (2006) stipulate that the term “service” is not limited to computer-based applications but extends to the functions of the company or networked enterprises. Resources such as a computer, a machine or a human are responsible for providing services. Issues associated with interoperability of service are usually to do with the description (in terms of syntax and semantics) of the services required and provided, the ICT support for service delivery and the organisational aspects related to the management of service exchange (Chen & Daclin, 2006).

The interoperability of processes

Chen et al (2008b) posit that process interoperability allows different processes to work in a coordinated manner. In this context, a process entails a set of procedures or jobs for a company. The ability to interconnect the in-house procedures of a pair of organisations is essential for creating a common process in a networked environment. According to Chen and

Daclin (2006) barriers typically hinder process interoperability. Examples are various syntax and semantics used in languages that model business processes or workflows (conceptual barriers), discordant process implementation instruments and platforms (technological barriers) as well as different process organisation mechanisms, configurations and management (organisational barriers).

<u>The interoperability of business</u>

Business interoperability entails working amicably within a company or organisation regardless of dissimilar forms of work practices, culture, commercial approaches, legislation and decision making styles, to name a few. In other words, interoperability of business focuses on a business entity and should be perceived and understood without vagueness and obscurity among interoperating parties.

3.2.3 Interoperability approaches

These consist of methods for eliminating the interoperability barriers identified earlier on. According to ISO 14258 (Chen, 2006) the Integrated, Unified and Federated approaches are the basic ways of relating systems to one another thus making systems interoperable.

<u>The integrated approach</u>

In the integrated approach, all models of systems are built based on a common template (Chen and Daclin, 2010). Various representations and prototypes are developed and explained using a shared format or template. This structure (format) should be as comprehensive as the prototypes themselves. In an integrated approach, conceptual and business-aligned modelling languages are used for representing the requirements of users. The enterprise models are then converted to models that are more technology-dependent, thus enabling implementation of the designed system (Chen & Doumeingts, 2004). The integrated approach aims to achieve overall consistency of the system. Different units or building blocks of the system are planned and executed by means of a shared or mutual format or standard. This enables interoperability to be understood as a design-in quality of the system's constituent elements. Using the integrated approach, the interoperability of various components can be achieved without additional interfacing efforts (Chen & Doumeingts, 2004).

Chen and Doumeingts (2004) stipulate that the Graphs with Results and Actions Inter-related (GRAI) decisional approach and the Computer Integrated Manufacturing Open System Architecture (CIMOSA) are examples of implementations of the integrated approach to interoperability. The GRAI is focused on consistent and extensive decision making. Integration by decision refers to making decisions within various functions in such a way that there is consistency, thus contributing to the achievement of the enterprise' overall objectives. A specific example is decision-making for load-levelling in the field of production management. This is a complex task that needs a set of consistent decisions. In this case, using a common format like the GRAI grid language enables the decision system designed to facilitate interoperations among various decision points of the system. The GRAI method can be used to represent and analyse the processes of a production activity (Chen & Doumeingts, 2004).

CIMOSA is an enterprise modelling framework which is intended to support the integration of computers, machines and people at enterprise level. CIMOSA offers a modelling language, supporting technology and a methodology to ensure its goals are met. Developing a CIMOSA system entails that all the parts of the system must be planned (designed) and executed using CIMOSA templates or constructs.

<u>The unified approach</u>

In the unified approach, all models of systems are built based on a common template that exists at medium level or meta level (Chen and Daclin, 2010). This common format is non-executable, contrary to the case with an integrated approach. The unified approach is more applicable in a heterogeneous scenario characterised by disparate systems that were designed using different templates or formats. In order to accomplish interoperability between these varied and dissimilar elements, using the unified approach, an agreement must be reached to come up with a common neutral format that is defined at meta-level or medium level. Information exchange is then achieved through mapping systems to the meta-model (Chen and Doumeingts, 2004). The advantages of the unified approach compared to the integrated approach are decreased efforts, cost and time when implementing systems.

According to Anaya et al. (2010) emerging ICTSs are increasingly becoming model-driven. The reason for this trend is that with model-driven systems a change in the system template inevitably leads to a resultant change in the implemented system without needing system re-design and re-implementation. However, this is best accomplished by models expressed in interoperable languages, for instance the Unified Enterprise Modelling Language (UEML) and the Process Specification Languages (PSL).

The UEML is designed to offer an unchanging interface to enterprise prototyping mechanisms and an unbiased pattern for data interchange of enterprise prototypes or systems. In order to interoperate with networked partners, a new organisation just needs to map its own system/model to the neutral meta format or meta-template without changing its own system or model (Chen and Daclin, 2010). UEML is therefore intended to work as a centre that links various languages together with different prototypes articulated in such languages and is meant to be one of the means of enabling interoperability between information systems and models in an enterprise (Anaya et al., 2010).

According to Grüninger and Menzel (2003:63) the "Process Specification Language (PSL) has been designed to facilitate correct and complete exchange of process information among manufacturing systems, such as scheduling, process modeling, process planning, production planning, simulation, project management, work flow, and business-process reengineering". Thus, PSL aims to offer a common illustration for integrating several process-oriented applications during the course of the manufacturing process. In this case, the PSL acts as a neutral format or model that enables interoperability of interested systems through it, without requiring individual systems to be changed.

The federated approach

In the federated approach, there is no pre-defined common format or data model enforced at the ecosystem system level and for that reason platforms are free to choose any proprietary data model or standard to use for interoperability (Deshmukh, Jayakody, Schneider & Damjanovic-Behrendt, 2021). In the federated approach, creating interoperability entails entities interchanging information “on the fly” which in this context implies that model mapping is achieved dynamically through negotiation (Tu, Zacharewicz & Chen, 2016). In this method, entities do not impose their approaches, languages and prototypes. Partners therefore need to share ontologies (Chen & Daclin 2010). Deshmukh et al (2021) concur that inter-linkages between mechanisms and offerings of disparate environments are created on ad hoc basis via an instance. This means the entities have to share the logic required to enable mapping amidst their data prototypes thus achieving data interchanges and interoperability. The federated approach is more suitable for virtual enterprises where diverse companies join their resources and knowledge for a short period of time, to manufacture a product (Chen & Daclin 2010). An example is the Data Spine platform enabler that connects the Internet of Things (IoT) interoperability gaps while creating an ecosystem of disparate Internet of Things environments in the manufacturing engineering field. The Data Spine enables the ecosystem to be extensible in such a manner that it is able to incorporate new tools, services and platforms (Deshmukh et al., 2021). The advantages of the Data Spine over the traditional approach of having users joining multiple platforms separately, include; provision of a low-code development environment in support of interoperability, single sign-on and an easy creation of cross-platform applications (Deshmukh et al., 2021).

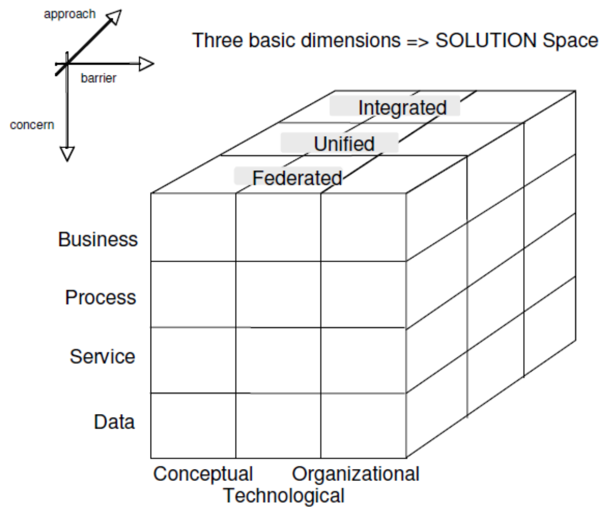

Figure 3.1: Framework for Enterprise Interoperability

Source: Chen and Daclin (2006)

The discussion above presented the major interoperability frameworks namely the IDEAS framework for interoperability of 2003, the ATHENA interoperability framework of 2003 and the Framework for Enterprise Interoperability of 2010. From this pool of interoperability frameworks, the Framework for Enterprise Interoperability (FEI) of 2010 was chosen as the "theory" underpinning this research study, also known as the theoretical framework.

The choice of the Framework for Enterprise Interoperability (FEI) was influenced by the following considerations. Firstly, the FEI is inspired from and well-grounded in the following foundational interoperability approaches: Levels of Information Systems Interoperability (LISI) of 1998, IDEAS interoperability framework of 2003, European Interoperability Framework (EIF) of 2004 and the ATHENA interoperability framework of 2003 (Chen and Daclin, 2010).

Secondly, the FEI is often cited as one of the foundational works in enterprise interoperability (Rezaei, 2014). Thirdly, FEI promotes a better understanding of research problems related to enterprise interoperability (Chen and Daclin, 2010). Fifth, the FEI is part of the draft International Standard, CEN/ISO 11354 elaborated by CEN TC310/WG1 and ISO TC184 SC5/WG1 (Chen and Daclin, 2010).

According to Kivunja (2018), an existing theory sometimes requires modification for it to be able to offer reasonable explanations of the interpretation of research data. This implies that a theoretical framework comprises a theory in a field of study that has been modified in order to address a particular research problem and research questions. The Framework for Enterprise Interoperability (FEI) by Chen and Daclin (2006), was adapted to this context of e-health interoperability. The following section discusses the adapted model.

3.3 Adaptation of the Framework for Enterprise Interoperability (FEI) to the context of e-health interoperability

The components constituting the FEI are interoperability barriers, interoperability concerns and interoperability approaches. This study adopted the interoperability barriers and Interoperability approaches constructs of the FEI. However, interoperability concerns were not considered. Interoperability concerns in the FEI refer to the various perspectives from which interoperability can take place namely interoperability of data, interoperability of service, interoperability of process and interoperability of business (Chen and Daclin, 2010). However, considering that there are other viewpoints of interoperability (such as device interoperability) in addition to those four specified in the FEI, leaving out interoperability concerns was regarded as a better option, lest the researchers would be blamed for leaving out certain interoperability concerns that would be relevant in other healthcare settings. In addition, interoperability concerns were considered as addressing the finer details of interoperations that take place amongst interacting enterprises, thus they were not included in this study's theoretical framework since the research is intended to give a general framework for adopting interoperability in healthcare, without prescribing the perspective from which interoperability would be taking place.

Thus, in terms of interoperability barriers, technological and organisational barriers were adopted with their original context, however, Conceptual barriers were also adopted with the original context however renamed to terminology barriers since the word "conceptual" appeared not to convey the subject of terminology and standards. The word "terminology" was preferred since it conveyed the intended meaning at face value.

Legal and regulatory barriers were added into the adapted framework as they play a critical role in e-health interoperability. According to Brandt, Rietkerk, Rijken, van Bekkum & Stroetmann (2015) an appropriate regulatory framework is one of the critical successful factors for e-health interoperability in sub-Saharan Africa. Khumalo (2017) concurs that legislation and policies are vital in e-health (and subsequently e-health interoperability) since the field is vulnerable to privacy breaches and technological obsolescence in the process of sharing health information across various health facilities.

Therefore, the study's adapted theoretical framework comprised of interoperability barriers and interoperability approaches:

a) Interoperability barriers

These refer to interoperability impediments and are classified as technological, organisational, terminology as well as legal and regulatory barriers.

- Technological barriers

Technological barriers are related to the non-compatible nature of information technologies in terms of configuration, architecture and environments. In other words, technological barriers are due to a lack of compatible standards for enabling heterogeneous computing devices to exchange information between at least two implementations. Forms of technological barriers include messaging barriers such as non-compatibility of communication protocols, content barriers such as incompatibility of techniques used to represent information and infrastructure barriers like the use of incompatible middleware platforms.

- Organisational barriers

These barriers refer to the non-compatibility of organisational setups and management methods used in various organisations. In addition, these factors refer to the definition, authority and responsibility aspects of organisations. Some aligning would have to be undertaken before two entities can interoperate at the working level. Major issues are related to authority, such as who is authorised to do what; as well as organisational structure, whether it is centralised or decentralised, hierarchical or matrix or networked organisation structures.

- Terminology barriers

Terminology barriers are about differences in semantics and syntax, in information exchange. Incompatibility of a syntactic nature can exist where various people or implementations make use of varied arrangements for representing information. One instance is the use of the Unified Enterprise Modelling Language (UEML) that offers a neutral format for data exchange of enterprise models/systems. UEML therefore acts as centre that connects various languages and their prototypes. UEML is meant to facilitate interoperability between information systems and models in an enterprise (Anaya et al., 2010).

On the other hand, semantic interoperability facilitates the unambiguous understanding of information. Semantic annotation and reconciliation that uses ontology is the current known technique for solving challenges of semantic interoperability. An example is the use of the Simple Protocol and RDF Query Language (SPARQL) that enables transparent interactions with Internet of Things (IoT) networks centred on the Web of Things (WoT). In this case the meta data of IoT devices are described using ontologies (Cimmino, Poveda-Villalón & García-Castro, 2020). Terminology barriers focus on challenges associated with the format and meaning of information.

- Legal and regulatory factors

Legal and regulatory factors relate to issues of law such as the required legal and policy framework for e-health interoperability. The other component of the FEI that was adopted was interoperability approaches which are methods of eliminating interoperability barriers. According to ISO 14258 (Chen, 2006) the Integrated, Unified and Federated approaches are the basic ways of relating systems to one another so as to establish interoperations. For this study, the federated approach was not considered since it is a growing approach that is still regarded research in progress (Tu et al., 2014). Thus mature interoperability approaches namely the integrated and unified approaches were preferred for this study. The Integrated and Unified approaches were adopted and renamed to closely-coupled and loosely-coupled respectively. This renaming was necessary to convey the degree of interdependence between modules in software, which is a critical aspect as far as e-health interoperability is concerned. In this regard, the context remained the same that organisations can adopt either closely-coupled systems or loosely coupled systems as a way of eliminating hindrances to interoperability efforts.

b) Interoperability approaches

These consist of methods of eliminating interoperability impediments, namely closely-coupled systems or loosely coupled approaches.

- Closely-coupled approach

In a closely-coupled approach, there is high dependence amongst modules in the system. This makes it difficult to make changes to the software, since a modification in one module would likely cause changes in the dependent modules. In terms of the degree of coupling, Chen, Doumeingts and Vernadat (2008) posit that a tightly coupled or closely-coupled setting implies that components are mutually dependent and inseparable. Vernadat (2010) elaborates that a closely-couple or tightly-coupled approach is characterised by components that are distinct, but any adjustment or change in any one of them results in a direct impact on the other components. A closely-coupled approach is not favourable for interoperability since it is rigid thus opposing the tenets of interoperability which are flexibility and ability to connect to other systems without depending on the individual modules.

- Loosely-coupled approach

In a loosely-coupled approach, system components (modules) are not dependent on one another, though connected. In this approach, modules are connected in such a way that the failure of one component does not affect the rest of the system components. Chen et al. (2008) posit that with a loosely coupled approach constituent elements are connected, interact and can exchange services through a communication network while preserving their individual logic of operations. Vernadat (2010) postulates that with a loosely-coupled approach, component systems are autonomous and exist independently, but they can work together for the common cause of interoperability. This approach supports systems interoperability since they can connect to other systems with minimum or no dependence on the constituent modules elements.

This chapter also highlights the deficiencies of the "theories" related to interoperability, found in literature. There was one "theory" in literature which was still a proposal that was yet to be tried and tested by other researchers. This was "A theory of interoperability failures" proposed by McBeth (2003). This theory proposal considered the interoperability of two systems over time. The theory was based on the life distribution model of the "Bathtub" curve to demonstrate the failure rate of electronic devices as they age over time. Thus, the theory suggested an interoperability failure rate characterised by three distinct epochs namely early, immediate and relative obsolescence, based on the “bathtub curve”. This theory did not qualify to be included in the study the theoretical framework because its focus is interoperability failures over time whilst the thrust of this research is on enterprise interoperability as a whole.

Efforts to come up with a theory for interoperability were also evidenced by a PhD thesis entitled “Towards a formal theory of interoperability” by Diallo (2010) aimed at providing the initial step towards a formal theory of interoperability in systems modelling and simulation.

3.4 Conceptual framework adopted in this study

McTaggart (2021) posit that a conceptual framework describes in narrative or graphically the major issue under study through presenting the relationship between the main aspects and variables. Edom et al (2010) concur that a conceptual framework is a configuration (structure) developed by the researcher, that clarifies the development of the phenomenon under study. A conceptual framework is the researcher’s understanding of the association among the various variables in a research study. It entails the researcher’s understanding of the problem under study and how it will be investigated. Miles and Huberman (1994) posit that a conceptual framework shows the variables, constructs, and major factors as well as the relationships among them. Adom et al. (2018) further concurred that a conceptual framework is a researcher's personally constructed model that they use to explain the relationship between the main variables of the study. This means a conceptual framework, is not ready made, but should be developed by the researcher.

This research study's conceptual framework was derived from Chen and Daclin's framework for enterprise interoperability of 2010. This framework enabled the researcher to articulate the conceptual framework where the researcher demonstrated their comprehension of the problem under investigation. In addition, it is not the intention of this study to prove or repudiate a theory. The study aims to explain the current status of e-health, the current status of e-health interoperability, the barriers and enablers of e-health interoperability and finally to develop a framework for implementing e-health interoperability in developing country contexts.

In most cases, diagrams are generated to clearly explain the variables or constructs of the research topic and the associated relationships (Adom et al., 2018). In this regard, a graphic illustration of the conceptual framework underpinning this research study was given. In addition, the conceptual was also accompanied by its description. This was in accordance with Fisher (2007) in Adom et al. (2018) that, a good conceptual framework must also be articulate in writing so that it is better understood. In terms of the presentation of the conceptual framework, Crawford (2020) advocated for a narrative presentation accompanied by a graphical representation of the narrative. Thus, the conceptual framework's graphical representation was also explained.

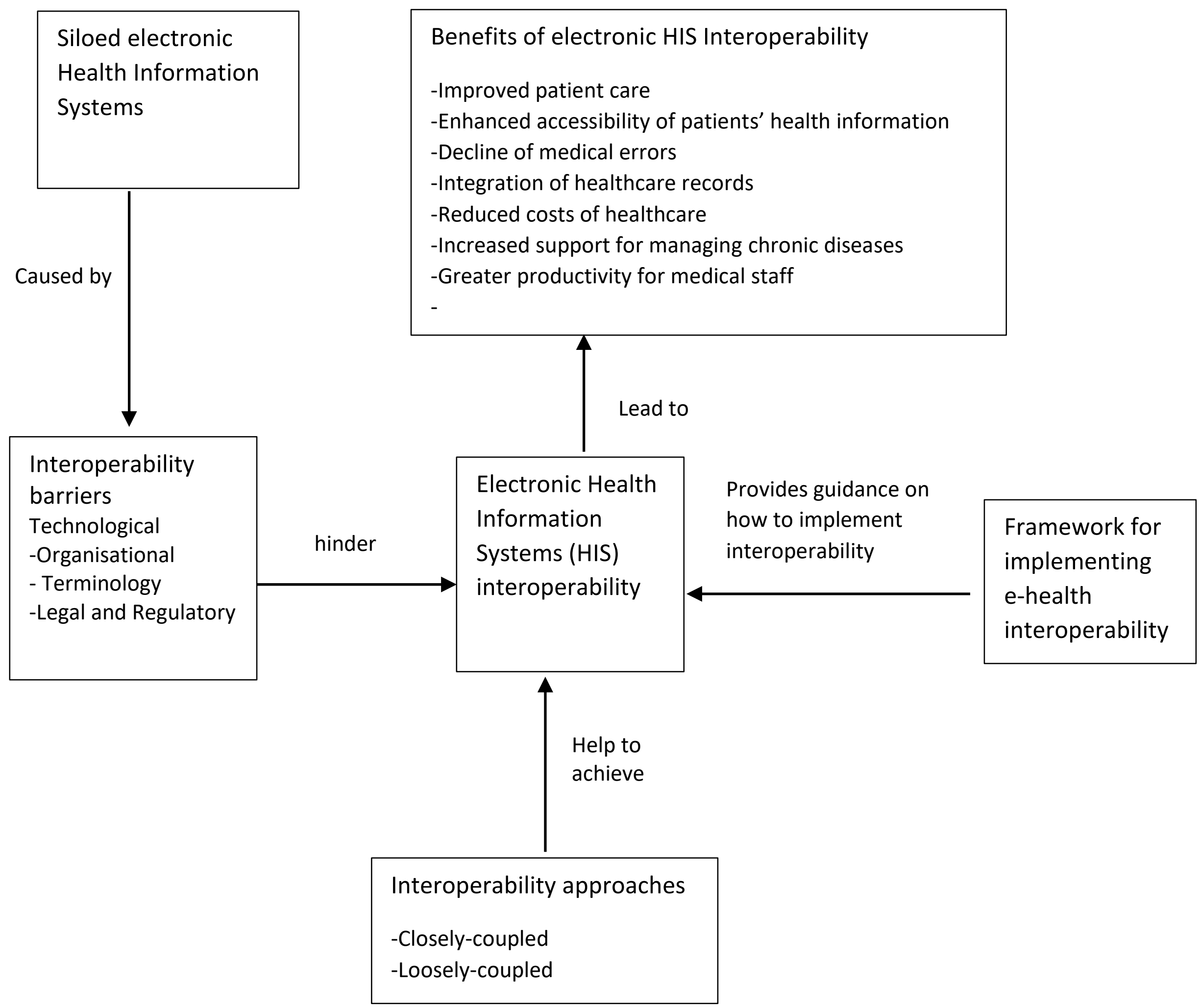

Figure 3.2: Conceptual framework

Source: Researcher's own

The conceptual framework in figure 3.2 shows three main pillars upon which this research study is based, that is, interoperability barriers, interoperability approaches and a framework for e-health interoperability. Firstly, the conceptual framework posits that currently, health information systems in Zimbabwe are not interoperable. The lack of interoperability among health information systems in Zimbabwe is due to the technological, organisational, terminology as well as legal and regulatory barriers to interoperability. The net effect is the fragmentation of HIS in Zimbabwe. The framework further suggests that interoperability approaches, either closely-coupled or loosely-coupled can be used to achieve electronic HIS interoperability. A framework for implementing interoperability in e-health serves to suggest guidance to governments and other stakeholders on what to do in pursuit of interoperability.

3.5 Summary

The chapter then discussed the theoretical framework, that is, the Framework for Enterprise Interoperability by Chen and Daclin (2006). The adaptation of the FEI to the context of e-health interoperability was also presented. The chapter then discussed the conceptual framework adopted for this study and concluded by a summary. The methodology chapter now follows.

CHAPTER 4

METHODOLOGY

4.1 Introduction

Kothari (2014) defines research methodology as a means of solving a research problem systematically. Kothari (2014) maintains that a research methodology entails the researcher scrutinising the procedure followed for examining the research problem whilst articulating why particular research methods and techniques were adopted over others. Research methodology also comprises of details of the research process such as an explanation of how the research problem was defined, hypothesis formulation, what data was collected as well as justification for data analysis methods used (Kothari, 2014). This chapter presents the research design for this study, data collection procedure, document review, data analysis. Trustworthiness and ethical consideration.

4.2 Research paradigm

Guba and Lincoln (1994) posit that a paradigm refers to a basic belief system that is founded on epistemological, ontological and methodological assumptions. Rehman and Alharthi (2016:51) concur that "a paradigm is a basic belief system and theoretical framework with assumptions about 1) ontology, 2) epistemology, 3) methodology and 4) methods". Furthermore, Guba & Lincoln (1994) agree that paradigms refer to basic belief systems that are based on ontological, epistemological and methodological assumptions. Put differently, a research paradigm refers to the manner in which one comprehends the reality of the world they want to study. According to Mackenzie and Knipe (2006) cited in Kivunja and Kuyini (2017) the term paradigm in research, refers to the "world view" of the researcher. Consequently, the interpretation or meaning of research data is also influenced by the researcher's worldview or school of thought (Kivunja & Kuyini, 2017). A researcher's paradigm is critical in that it is "the conceptual lens through which the researcher examines the methodological aspects of their research project to determine the research methods that will be used and how the data will be analysed" (Kivunja & Kuyini, 2017: 26). Therefore, the research paradigm determines the course of the research process together with the methodology and methods adopted.

4.3 Components of a research paradigm

Lincoln and Guba (1985) cited in Kivunja and Kuyini (2017) postulate that there are four components that make up a paradigm namely; ontology, epistemology, methodology and axiology. Saunders, Lewis & Thornhill (2019:133) refer to these four as "types of research assumptions to distinguish research philosophies". Kivunja and Kuyini (2017) agree that the stated four components namely; ontology, epistemology, methodology and methods (or axiology), contain basic assumptions and beliefs held by each research paradigm. Grix (2019), refers to these elements of a research paradigm as "building blocks of research" and also identifies these as, ontology, epistemology, methodology and methods. Grix (2019:74) propounds that "ontology and epistemology are to research what 'footings' are to a house: they form the foundations of the whole edifice". Furthermore, Grix (2019:75) asserts that "ontology and epistemology can be considered as the foundations upon which research is built". Grix (2019) further elaborates that methodology, methods and sources build upon our assumptions of ontology and epistemology. Dammak (n.d.) agrees that a researcher's choice of methodology and methods are informed by his or her ontological and epistemological assumptions. For this reason, this section will discuss these two (ontology and epistemology) elements or assumptions of a given research paradigm.

4.3.1. Ontology

According to Saunders et al. (2019:133), "ontology refers to assumptions about the nature of reality". Scotland (2012) cited in Kivunja and Kuyini (2017) agrees that ontology is a line of philosophy associated with assumptions one makes so that they believe that something is real or makes sense. According Grix (2019) ontology simply refers to "what is out there to know about". Kivunja and Kuyini (2017) concur that ontology helps one to mentally visualise the nature of realism and what one believes can be acknowledged concerning reality. Blaikie (2000:8) cited in Grix (2019:76) comprehensively define ontology as:

> *"claims and assumptions that are made about the nature of social reality, claims about what exists, what it looks like, what units make it up and how these units interact with each other. In short, ontological assumptions are concerned with what we believe constitutes social reality".*

Kivunja and Kuyini (2017) elaborate that philosophical assumptions about what is real are fundamental in understanding how one interprets data collected. These assumptions play a role in adjusting one's thinking concerning the research problem, its importance as well as how one might contribute towards its solution.

Don-Solomon and Eke (2018) assert that the ontological assumption has two stances namely objectivism and subjectivism. Objective ontology asserts that social phenomena together with their meanings exist independent of social actors (Don-Solomon and Eke, 2018). O'Gorman and McIntosh (2015) concur that with objectivism reality exists even without interacting with social actors. Thus, an objective ontology believes that reality exists even in the absence of social mediators and holds that establishing and explaining world ethics is possible using robust and reproducible means. On the contrary, a subjective ontology perceives reality as consisting of interactions and perceptions of living subjects. O'Gorman and McIntosh (2015:56) posit that "a subjective perspective looks at reality as made up of the perceptions and interactions of living subjects". Hudson and Ozanne (1988) cited in Don-Solomon (2018) agree that with subjectivism the researcher as well as the societal phenomenon being studied are dependent and mutually interrelated. This research study follows a subjective ontology as it was characterised by constant interactivity between the researcher and the participants associated with the aspect under study. The research process also included immersion in the study data via reading and re-reading of interview transcripts, listening and replaying interviews in order to know them in detail.

4.3.2 Epistemology

Gall, Gall and Borg (2003:13) cited in Rehman and Alharthi (2016) define epistemology as "the branch of philosophy that studies the nature of knowledge and the process by which knowledge is acquired and validated". In other words, epistemology basically refers to the means we get to know of something, or how we acquire knowledge. Grix (2019:81) distinguishes ontology from epistemology by elucidating that "if ontology is about what we may know, then epistemology is about how we come to know what we know". Grix (2019) simply puts epistemology as "how can we know about it", or further simplified to "how we know". To sum this up, epistemology focuses on methods of knowledge acquisition and methods of disseminating knowledge to other individuals. Merriam and Tisdell (2015) postulate four types of epistemological perspectives namely positivist, interpretivist or constructivist, critical and post-modern or post-structural. Out of these four perspectives, positivism and interpretivism are considered the major ones and are therefore presented.

4.3.2.1 Positivism

A positivist approach holds that reality exists "out there" and that it can be observed, measured and is stable (Merriam and Tisdell, 2015). Rehman and Alharthi (2016) agree that researchers discover knowledge by observing the aspect under study without disturbing or affecting what is being observed. Language and symbols are used to describe study objects as they exist in their real form without interfering with them. According to David and Felix (2002) cited in Don-Solomon and Eke (2018), positivists usually use quantitative research methods such as experiments and surveys since these are objective and the results are generalisable and replicable too. The kind of generalisability applicable in this case is the type EE generalisability that is, generalising from data to description where generalisation is from empirical statements to other empirical statements (Lee and Baskerville, 2003). Wellington (2000) cited in Al-Saadi (2014) concurs that positivist knowledge is considered to be objective, generalisable and replicable, thus positivism is perceived as the scientific method. Ideally, the scientific method entails carrying out experiments so as to explore observations, thus searching for cause and effect relationships in nature (Kivunja and Kuyini, 2017).Furthermore, the positivist approach is fundamentally deductive and characterised by formulation and testing of hypothesis, mathematical equations and calculations to derive conclusions (Kivunja and Kuyini, 2017).

4.3.2.2 Interpretivism

According to Al-Saadi (2014), in the interpretivist approach, knowledge is created by exploring and comprehending (and not discovering) the social environment of the society under study while focusing on their meaning and interpretations. Furthermore, using the interpretivism approach, social actors in a specific context socially construct meaning. In the interpretivist approach researchers build and create meanings and interpretations based on that of their research participants (Al-Saadi, 2014). Interpretivism is founded on naturalistic methods of collecting data, like observations and interviews. Using interpretivism, it is impossible for the researcher to separate himself or herself from the research, these two entities actively engage in the research, resulting in findings being influenced by their values and perceptions. In addition, the interpretive methodology is associated with the qualitative approach. Moreover, the research process for a positivist approach is essentially inductive, since the goal is to produce a supposition using collected data, and, not to test an existing theory using collected data (Al-Saadi, 2014). This research study employed the interpretivist approach since it satisfied all the characteristics of interpretivism. This research study employed the qualitative methodology, semi-structured interviews were used to collect data and a framework for implementing e-health interoperability was developed based on the data collected.

Furthermore, the researcher closely interacted with the research participants with the aim of constructing meanings concerning e-health interoperability.

Figure 4.1 illustrates the differences between the positivist and interpretivist approaches.

Positivist paradigm		**Interpretivist paradigm**
Concentrate on facts	⟺	Concentrate on meaning(s)
Search for causality and essential laws	⟺	Try to appreciate what is taking pace.
Reduce phenomena to simplest elements	⟺	Look at the totality of each situation
Formulate hypotheses and test them	⟺	Develop ideas through induction from the data
Operationalise concepts so that they can be measured	⟺	Use multiple methods to establish different views of phenomena
Take large samples	⟺	Small samples investigated in depth over time

Figure 4.1: Difference between the positivist and the interpretivist approach

Source: O'Gorman and McIntosh (2015)

4.4 Research Design

Sekaran and Bougie (2016:95) state that "a research design is a blueprint or plan for the collection, measurement, and analysis of data, created to answer your research questions".

Sekaran and Bougie (2016) identified six types of research study designs, namely, experiments, survey, ethnography, case studies, grounded theory and action research. This study pursued the case study research design.

4.4.1 Case study

Yin (2003:13) defines a case study as "an empirical inquiry that investigates contemporary phenomenon within its real life context". In a case study, the research focus is on collecting information concerning a particular unit such as a business unit or a community. It is a detailed study of an entity of interest.

This study employed the case study research design. In this context, the phenomenon under study, e-health interoperability in Zimbabwe, had not been widely researched and also the outcome could not be pre-determined. E-health interoperability is a topical issue in healthcare globally, including Africa and Zimbabwe. In healthcare, the trend is now towards efficient exchange of clinical data among heterogeneous health information systems to improve the availability of patient data and hence advance the standard of healthcare. This study was a detailed investigation of the Zimbabwean healthcare system to determine the level of health information systems' interoperability. Data that was collected in this study informed the design of the framework for implementing e-health interoperability in Zimbabwe. In addition, this research study is unique in the Zimbabwean setting, since thus far it is the first research to be conducted on implementing e-health interoperability using a framework. In this context, a preliminary literature review on e-health resulted in the formulation of a preliminary guiding mind map or structure for the study. The guiding mind map resulted in the crafting of research objectives that were aligned with a suitable framework within e-health interoperability research. This process consequently resulted in the development of the theoretical and conceptual frameworks that were proposed in this study. An interview guide was developed based on the research objectives. Results from the collected data were analysed and discussed. These findings were then incorporated in the framework that was developed for implementing e-health interoperability in Zimbabwe.

4.4.2 Research approach

The two major approaches to research are the quantitative approach and qualitative approach (Kothari, 2004). The qualitative approach was chosen for this study. With qualitative research, the aim is to find out the fundamental reasons plus motives concerning the phenomenon under study. In this study the aim was to find out the central issues regarding the interoperability of electronic health information systems.

According to Landman (2002) cited in Grix (2019) qualitative research is characterised by using research methods that scrutinise underlying qualities of a particular phenomenon. Dawson (2002) elaborates that qualitative research endeavours to get an in-depth point of view from participants and hence fewer people participate in the research although the researcher and participants interact for longer periods of time. Interviews and focus groups are typically used for collecting data. This research study was of a qualitative nature in which few participants were interviewed and the involvement between the participants and the researcher was prolonged. The qualitative research approach was ideal for this study since there was need to get an in-depth understanding of the implementation of e-health interoperability in developing country contexts. This is in accordance with Hammarberg, Kirkman and de Lacey (2016) who posit that a qualitative approach is useful for answering questions pertaining meaning, experience and perceptions, usually from the participants' viewpoints. In accordance with qualitative research structured interviews and document review were used to gather data from research participants.

4.4.3 Data collection

This section presents a discussion of the chosen target population, sampling methods employed and a discussion of the data collection process.

4.4.3.1 Target population

This study's target population was guided and aligned to "critical interoperability healthcare players" proposed by Gambo, Oluwagbemi & Achimugu (2011) that comprises of healthcare companies, healthcare providers, IT and administrative staff and government health authorities. Thus, the target population for this study comprised of e-health experts from the Health ministry in Zimbabwe, e-health systems developers (in the public and private sectors), vendors of health IT systems and Non-Governmental Organisations (NGOs) active in e-health implementation and support such as Jembi Health Systems.

4.4.3.2 Sampling methods

The sampling method employed in this study was purposive sampling. According to Cohen, Manion & Morrison (2007) purposive sampling entails researchers handpicking participants constituting the sample based on their judgement or possession of the specific characteristics being sought for. Ishak and Bakar (2014) concur that the purposive sampling procedure makes use of the researcher's expertise to select cases bearing a specific purpose in mind. Ishak and Bakar (2014) further posit that purposive sampling is ideal for a case study especially when an investigator wants to select unique participants that are particularly informative of the phenomenon under study.

4.4.3.3 Sample size

In a qualitative research study, it is not possible to pre-determine the size of the sample before the commencement of the data gathering exercise. Ishak and Bakar (2014:30) concur that "qualitative researchers rarely determine their sample size prior to their study". In addition, Ishak and Bakar (2014:30) elaborate that "qualitative researchers select their cases gradually, and not limiting the number of selected participants until the data reaches saturation point". Marshall (1996:523) concurs that "the number of required subjects usually becomes obvious as the study progresses, as new categories, themes or explanations stop emerging from the data (data saturation)". Thus, the size of the study's sample could not be pre-determined since this is typical of a qualitative study.

Since qualitative research strives to get a deeper understanding of a phenomena from participants, fewer people are engaged in a research study (Dawson, 2002). This led to this research study having a total of ten participants. Furthermore, e-health interoperability is a specialist domain within healthcare, hence only a few expert participants comprised the sample. When data collection commenced, participants were added gradually added onto the sample, until saturation point was reached.

4.5 Data collection procedure

This section details how data was collected using interviews and document review.

4.5.1 Interviews

Semi-structured interviews were conducted with 10 research participants in a face to face mode. An interview guide with a list of open-ended questions was developed, containing the questions in a particular order. The open-ended nature of the questions defined the topic that was being investigated while providing the interviewer and interviewee an opportunity to discuss the topic in greater deal. The interview guide also enabled the interviewer to follow the guide so that the discussion is guided. Semi structured interviews were ideal for collecting research data since the interviewer had a number of areas that had to be addressed and also that there was only one chance to interview each respondent who indicated that they were very busy people. To avoid participants being distracted from their normal work duties, the researcher interviewed each participant in their office or place of work. The average duration per interview was one hour. During the interviews, a recording device was used to record each interview. The respondents were also asked impromptu questions as a way of gathering more information on the topic under study. The collected data was useful in informing the development of the framework for implementing e-health interoperability in a developing country context. Interviews were considered ideal for data collection since there was need for the researcher to get a deeper comprehension of the matters pertaining to e-health implementation and e-health interoperability in Zimbabwe. The characteristics of the interview informants are shown in Table 4.1. A professional transcriber was used to transcribe the interviews. The researcher then verified all the interview transcriptions before data analysis commenced. Table 4.1 shows that the research participants had varying expertise and were drawn from various organisations such as the health Ministry and those that develop e-health systems. The group of participants held either management or technical expert roles in their organisations. In addition, the participants comprised of those working for private, public and not-for-profit organisations. The varied characteristics of participants indicated that the group lacked bias.

Table 4.1 Summary of interview informants

Participant Number	Type of organisation	Management or non-management	Expertise	Sector (Private, Public or NGO)
1	Health Informatics Training and research	Management	E-health expert	Public
2	Ministry of Health	Senior Management	Health Information Systems Management	Public
3	Development of e-health systems	Senior Management	E-health expert	Private and for-profit organisation.
4	International organisation for human care and improving health.	Non-management	Senior Developer for e-health systems	Not for profit Organisation.
5	Ministry of Health	Management	Medical Doctor	Public organisation (Government)
6	Software Development	Non-Management	Developer	Non-Governmental Organisation

7	Software Development	Non-Management	Functional Consultant	Private and for-profit organisation.
8	Improving human life and transforming health.	Top Management	Development of Health Information Systems.	Not for profit organisation.
9	Development of e-health systems	Senior Management	E-health expert	Not for Profit Organisation.
10	Development of e-health systems	Senior Management (CEO)	E-health expert	Not for Profit Organisation.

4.5.1.1 Interview guide

This section discusses the alignment of the interview guide to the research study's objectives. The interview guide had 11 questions and each of the questions was related to at least one of the study's objectives. Question 1 sought to identify the e-health systems being used in Zimbabwe listing them according to their categories. This question answered objective 1 which was "To determine the current status of e-health implementation in Zimbabwe". Identifying the e-health systems being used in Zimbabwe was the first thing to be do towards determining the current status of e-health implementation in Zimbabwe. As e-health systems were being identified, respondents commented on the use, successes, shortcomings and scale of implementation, for instance, which can all be used to explain the status of e-health implementation.

Interview question 2 sought to assess the level of maturity of e-health systems implementation. The level of maturity in this context refers to the progression of e-health systems implementation from low level to advanced level as well as the scaling up of pilot e-health projects or systems to proper information systems with a wider coverage or even national coverage (a HIS that is implemented and running nationwide). All these are variables or descriptors of Objective 1, that is, "To determine the current status of e-health implementation in Zimbabwe".

Interview question 3 aimed to establish whether "resource allocations were adequate for the implementation of e-health systems". In literature, whenever the status of e-health implementation is discussed, the issue of the adequacy of resource is also discussed. This means the adequacy of resources can be a descriptor for the status of e-health implementation. Thus, interview question 3 was also aligned with Objective 1.

Question 4 on the interview guide was "What is the current status of e-health interoperability in Zimbabwe?" This question gave answers to Objective 2 stated as "Determine the current status of e-health interoperability in Zimbabwe." Responses to this question constituted the general status of e-health interoperability in Zimbabwe.

Interview question 5, "What have been the successes in the implementation of e-health interoperability?" was also aligned with objective 2 and objective 4, that is to "Determine the current status of e-health interoperability in Zimbabwe" and the enablers to interoperability respectively.

"What have been the challenges in the implementation of e-health interoperability?" was question 6 on the interview guide. Difficulties, obstructions and impediments to e-health interoperability are what this question looked for, hence aligning it to objective 2 and objective 3. As respondents discussed the barriers to e-health interoperability, they also suggested what they thought would facilitate interoperability in e-health, thus fulfilling objective number 4 stated as "Determine the enablers in the implementation of e-health interoperability in a developing country context". Hence objective number 4 was answered as participants responded to question 6. In addition objectives 3 and 4 were derived from the interview data using thematic and content analysis. Barriers and enablers of e-health interoperability (objectives 3 and 4 respectively) were also derived from the interview responses of the participants.

Question 7, 8, 9 and 10 on the interview guide were based on this study's Conceptual framework, on figure 2.7, concerning interoperability barriers namely, technological, organizational, terminology as well as legal and regulatory barriers respectively. Responses to these questions gave details on the status of e-health interoperability in the country, with respect to the Conceptual framework.

Question 11 on the interview guide was the last one and it read "What are the impacts of the lack of e-health interoperability?" Interviewee responses to this question answered objective 5 which was stated as "Identify consequences of a lack of interoperability in a developing country context". Since semi-structured interviews were very effective for collecting data because probing questions and follow up questions made interviews respond freely and provide rich data relevant to this study.

Objective 6, "Develop a framework for implementing e-health interoperability in a developing country context" was the aim of this research study, hence it utilised information gathered from all the other objectives (1-5).

4.5.2 Document review

After analysis of the interviews, a document review was conducted. This was part of the triangulation process which is typical of qualitative research. Document review was carried out for purposes of corroborating and comparing findings from the interviews. In this regard the researcher collected relevant documents from the interviewees and downloaded others from the internet. Documents reviewed comprised of national health planning documents, government acts, bills, policies and charters, e-health interoperability documents as well as reports on health information systems.

4.6 Data Analysis

Interviews were analysed using thematic analysis. NVivo 12 software was used for analysing emerging themes, grouping them and exploring connections between themes to enable analytical insight.

4.6.1 Thematic analysis

According to Braun and Clarke (2006) cited in Kiger and Varpio (2020:2) “thematic analysis is a method for analysing qualitative data that entails searching across a data set to identify, analyse and report repeated patterns”. These repeating patterns build up the themes in thematic analysis. In this study the researcher studied the interview transcripts and listened to the recorded interviews several times. Similar codes or shared values were combined to come up with one theme as shown in Table 4.2.

Thematic analysis is a suitable method to apply when the researcher seeks to understand experiences, opinions or activities across a data set (Braun &Clarke, 2012 cited in Kiger & Varpio, 2020). For this reason, thematic analysis was employed in this research study. Themes and sub-themes that came out of this analysis were used for the development of the framework for implementing e-health interoperability in Zimbabwe.

4.6.1.1 Themes generated from the codes

Table below (Table4.2) shows themes and their associated emerging codes.

Table 4.2 List of themes generated from the codes in the study

Objective 1 - Determine the current status of e-health implementation in Zimbabwe. This objective was addressed by types of HISs and maturity levels of e-health systems implementation. **a) Types of Health Information Systems**		
	Theme	**Words under this theme / Synonyms**
1	Information systems for HIV/AIDS	ePMS, HIV, ART,
2	Logistics Information Systems	Navision, warehousing, NatPharm, procurement, stocking, distribution, Excel tool, drug stock status, over stocking, Electronic Logistics Information Systems (ELMIS), understocking, CR Form, Logistics Management Information System (LMIS).
3	Laboratory Information Systems	BikaLIMS (at National Reference Laboratory), Lab263, Laboratory Management Information Systems (LIMS).
4	Maternal Health Systems	Pregnancy, neonatal, postnatal
5	Point of care systems / Patient level systems	Electronic Health Record (EHR), Electronic Medical Record (EMR), ePOC
6	Hospital Information Systems	DHIS-2, ePMS, PACs, radiology, pharmacy, laboratory information systems, Navision, SAP Healthcare System, National EHR, Mois (Karanda Hospital), Hospital Management System (HMS), MedicalOne, IMMIS (In-Patient Morbidity and Mortality Information System).
7	Routine Health Information System	DHIS-2, IMMIS.
8	Pharmacy Systems	Dispense-ware, Profam, Windscripts
9	Private Sector Systems	Health 263, HMS263, Lab263, health263 switch, TriMed, UtanoX, Atametro Avenues, CIMAS, Corporate 24, Gonda clinic, Belvedere Medical Centre.

10	Administrative Systems	Billing, Patient registration, Budgeting, HR, Payroll, Human Resources Information System (HRIS), Practice Management Information systems

b) Maturity levels of e-health systems implementation

Theme	**Words under this theme / Synonyms**
Maturity levels of e-health systems implementation	Low level, level 1, level 2, data entry, basic analytics, just above average, very far, not yet there, 30% uptake, 3 out of 10, Low level maturity, intermediate level maturity, advanced level maturity, immature, basic level.

Objective 2

Determine the current status of e-health interoperability in Zimbabwe.

This objective is addressed by interoperability factors and interoperability approaches.

a) The **interoperability factors** are; Technological factors, Organisational, Terminology as well as Policy and regulatory factors.

	Theme	**Words under this theme / Synonyms**
1	Technological factors	Internet connectivity, availability of computers, servers, networking, technical “clout”, internet, electricity supply, capacity and skills, system down, domain experts, programmers, developers, software development, skills, technical expertise, Digital Square, compatibility of systems, hardware investments, security.
2	Organisational factors	Stewardship, donor-funded projects, government funded, ownership, private, public, personnel, buy in from stakeholders, change management, reporting structures, stakeholders, inadequate resources, cost, people maturity, mental maturity, perception, human-to-human interaction, human resources base, political factors, ignorance, errors of commission, leadership, vision, governance, organizational efficiency, transparency, enterprise approach, health facility registry , governance structures, governance documents, organizational structure, bureaucracy, re-structuring, alignment to e-health, financial resources, research and development, Community of Practice (CoP).
3	Terminology factors	Standards, HL7, IDC10, OpenHIE, semantics, international standards, TC215, Interoperability layer, CPC—Medicines, Standards for diagnosis, HL7 FHIR, DICOM for digital imaging, RUBID standard for interoperability layer, different health institutions use different standards, standard coding system.
4	Legal and regulatory factors	E-health strategy, national IT policies, procurement policies, Law, government intervention, legal framework, Patient Charter, legislature,

		government regulation(s), policy document, e-health governance institution, Data Protection Bill, ICT policy, political will, Health Professions Act, Patient Charter, Zimbabwe National Healthcare Strategy, Medical and Dental Practitioners Council of Zimbabwe (MDPCZ).

b) The **interoperability approaches** are; closely coupled and loosely coupled.

	Theme	**Words under this theme / Synonyms**
1	Closely coupled approach	Common, Integrated, dependent, National HIE, united, connected,
2	Loosely coupled approach	Heterogeneous, different, independent, varied, self-reliant, diverse, systems approach, state HIEs, disjoint, separate, OpenHIE, enterprise approach

Objective 5
Identify consequences of a lack of interoperability in a developing country context;

Effects of lack of interoperability

	Theme	**Words under this theme / Synonyms**
1	Burden on the health worker	Papers, registers, redundancy, repeated patient information
2	Poor patient care	Absence of complete patient medical record, mis- diagnosis, Continuity of care.
3	Decision making not easy for managers	Clinical decision, diagnosis, decision-making process.
4	Cost	Expensive, costly, budget, duplication of procedures, physical movement of lab results and/or medical record, repeat test, repeat procedures.
5	Inefficiency	Delayed care, duplicated patient records, failure to track results from lab, delay in communicating medical results, limited access to patient record, organizational inefficiency, difficult to update information, unsyncronised records, Inconsistent methods of patient records disposal, difficulty of sharing patient records, inadequate information available to a health service provider, compromised quality of care, difficulty in finding the nearest service provider, Lack of re-usability of systems already developed.
6	Wastage	Wastage of resources, wastage of drugs.

7	Abuse of system	Double purchases of drugs, double collection of drugs, abuse of drug collection system, difficulty to manage stock such as drugs.
8	Impedes innovation	Impedes innovation.

4.6.2 NVivo Analysis

NVivo analysis was carried out as part of thematic analysis and qualitative analysis focusing on word cloud, explore diagrams, comparison diagrams and cluster analysis. Word cloud was used to find out the main words that were said the most times with respect to the objectives. Explore diagrams helped in identifying sub-themes that had to be grouped together so that they could be incorporated in the framework for implementing e-health interoperability. Comparison diagrams were used to compare files (interview transcripts) in order to show similarities and differences in terms of what respondents contributed. Cluster analysis diagrams were also created to graphically illustrate the similarities or differences between nodes. Nodes that appeared close to each other were more similar (and therefore most likely constituted a theme), than those nodes that were far apart. The Jaccard's co-efficient is the similarity metric that was adopted for this study. The Jaccard's co-efficient values range from 0 to 1. Co-efficients nearer to 1 denote that the nodes are more similar while values closer to zero imply that the nodes are more dissimilar.

4.7 Trustworthiness

Trustworthiness refers to a sense of confidence in data, interpretation and methods a reader would have concerning a researcher's work (Stahl and King, 2020). Trustworthiness serves to ensure the quality of a qualitative research study. According to Korstjens and Moser (2018) the quality standards applicable to quantitative research such as reliability, internal validity, objectivity and generalizability are not appropriate to measure the quality of qualitative research. Instead for qualitative studies, researchers consider trustworthiness as a surrogate for validity and reliability. Nowell, Norris, White and Moules (2017) concur that according to Lincoln and Guba (1985) the notion of trustworthiness was introduced to mirror validity and reliability which are conventionally used as quality criteria for quantitative research. According to Lincoln and Guba (1985) the four pillars of trustworthiness are credibility, dependability, confirmability and transferability. Trustworthiness is defined as "How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of" (Lincoln and Guba (1985:290).

4.7.1 Credibility

Korstjens and Moser (2018:121) define credibility as "the confidence that can be placed in the truth of research findings". Credibility determines whether findings from research denote or characterize reasonable information gathered from the participants' original data and that it is a truthful explanation of the participants' original opinions. Tobin and Begley (2004) cited in Nowell et al (2017) posit that credibility pertains to the appropriateness between participants' opinions and the researcher's interpretation of them. Furthermore Lincoln and Guba (1985) cited in Korstjens and Moser (2018) assert that credibility resembles internal validity in quantitative research and is associated with the concept of truth value. Prolonged engagement, triangulation, persistent observation, peer debriefing and member check are the strategies used to ensure credibility. Out of these techniques, triangulation, prolonged engagement and peer debriefing were the strategies implemented in this study in order to achieve credibility. These techniques were convenient and easy to implement.

4.7.1.1 Triangulation

Triangulation involves examining evidence of information from different sources and using it to build a coherent justification for themes. Denzin (1978) cited in Lincoln and Guba (1985) defined triangulation as the use of several and diverse sources, methods, investigators and theories. In this regard, research data was collected from multiple sources (more than one data collection methods) namely semi structured interviews and document review. Semi-structured interviews were conducted to determine the level of electronic health implementation as well as the level of electronic health interoperability in Zimbabwe. In addition, a document review comprising of national health planning documents, government acts, bills, policies and charters, e-health interoperability documents as well as reports on Health Information Systems was also carried out to verify data collected from respondents.

4.7.1.2 Prolonged engagement

Spending prolonged duration in the field enables the researcher to develop an in-depth comprehension of the phenomena being studied. It also helps with conveying attributes of the site and people involved, thus making the narrative account more credible. According to Creswell and Creswell (2018:275) “the more experience that a researcher has with participants in their actual setting, the more accurate or valid will be the findings”. For this study the researcher spent 12 months in the field interacting with participants and investigating the issues under study.

4.7.1.3 Peer debriefing

This improves the accuracy of the study through involving a peer de-briefer, that is, a person who interrogates the qualitative study so that other people other than the researcher can understand the narrative. In this context, the researcher's supervisors played a significant role in this regard for the entire research study. In addition, a peer who is also a researcher from the researcher's institution conducted the peer de-briefing process.

4.7.2 Transferability

Korstjens and Moser (2018) define transferability as the extent to which the findings of a qualitative research study can be transferred to other contexts or settings with other participants. Thick description is one strategy that is used to ensure transferability in a qualitative research study (Lincoln and Guba, 1985). Thick description entails describing the behavior, experiences and their context so that it is meaningful to an outsider (Korstjens and Moser, 2018).

4.7.2.1 Thick description

Findings are conveyed using thick description. Detailed descriptions of the setting for instance, provided by the researcher usually provide several perceptions concerning a given theme, hence resulting in more credible research outcomes. In this regard, a comprehensive discussion is given on the research study's setting in chapter 1 and chapter 2. This includes an overview of Zimbabwe's health system with respect to the burden for disease, the country's health priorities, its successes and challenges as well as a general state of e-health systems implementation in the country.

4.7.3 Dependability

Dependability refers to the stability of findings over time (Korstjens and Moser, 2018). According to Lincoln and Guba (1985) dependability includes the aspect of consistency. An audit trail is the strategy for ensuring dependability. An audit trail requires the researcher to provide a comprehensive set of notes on how the research study was carried out including sampling, research material and how data was managed. An audit trail clearly describes the research steps taken from the beginning of research study until the reporting of the findings. Since this research study was a case study, a case study database was used to achieve dependability.

4.7.3.1 A case study database

A case study database is a well-structured compilation of the empirical evidence. It includes brief notes on the case study prepared by the investigator, documentation that was amassed in the process, transcripts of interviews and results of analysing the evidence. For this research study, a case study database was maintained and comprises of documentation gathered during the case study such as transcripts of interviews, national health planning documents, government acts, bills, policies and charters (which were later used for document review) and lastly analysis of the evidence.

4.7.4 Confirmability

Confirmability refers to the extent to which the outcomes of a research can be confirmed by other researchers (Korstjens and Moser, 2018). Lincoln and Guba assert that an audit trail is the strategy for achieving confirmability. According to Lincoln and Guba (989) cited in Nowell et al (2017) confirmability in ensured when credibility, dependability and transferability have been achieved. Thus, dependability and confirmability are both established through an audit trail which was discussed above under dependability.

4.8 Ethical consideration

An ethical clearance was sought from and granted by the College of Science, Engineering and Technology (CSET) at the University of South Africa. Authorisation to collect data was requested from and granted by the Ministry of Health and Child Care (MoHCC) in Zimbabwe and other e-health stakeholders. All the study's respondents provided their consent before data collection was conducted. The researcher also declared absence of any conflict of interest and avoided misrepresentation of findings so as to safeguard the truthfulness of this research study. According to Beauchamp and Childress (2001) the four essential ethical principles to consider when undertaking a research project:

4.8.1 Autonomy

Autonomy refers to an individual's freedom of choice pertaining participation in a research study, that is made without fear and coercion, but with knowledge and understanding of what the research project entails. In order to ensure such autonomy, the following steps were undertaken prior to interviewing each participant: i) participants were requested to indicate their willingness to take part in the research study; ii) if the participant was agreeable, then the context and details of the research study were explained to them. In the process, the researcher clarified concerns raised by the participant; iii) after the clarifications, the date, time and place of the interview were then agreed upon.

4.8.2 Non-maleficence

Non-maleficence aims to avoid causing harm to participants, whether it is harm of a physical or psychological nature. Accordingly, an ethical clearance was applied for and approved by the College of Science, Engineering and Technology at UNISA, in which matters to do with maleficence are addressed.

4.8.3 Beneficence

Beneficence refers to how the participants and community stand to benefit from the research study. This study is on e-health interoperability, which is the capability of information systems for health to exchange information and make use of the information exchanged. Interoperable health information systems have potential benefits including allowing timely access to patient information whenever needed, improving communication of medical information such as lab tests and results as well as eliminating repeated tests such as x-rays and scans, thereby reducing the cost of healthcare. The concept of interoperability in healthcare was also explained to participants. Nevertheless, it was made clear to participants that there were no incentives for participating in the research study.

3.8.4 Justice

Justice entails treating all participants equally without showing preferential treatment. In this study, fair treatment and respect were afforded to all the participants. Furthermore, those who participated in this research study did so, on purely voluntary grounds.

4.9 Summary

This chapter presented a comprehensive explanation of the research methods employed in this study. The epistemological and ontological perspectives adopted were also highlighted. The qualitative research approach was employed by means of a case study. Document analysis was also undertaken to corroborate findings from interviews. Purposive sampling was employed to identify the e-health interoperability stakeholders who were interviewed. Various strategies were employed to ensure that the credibility, transferability, dependability and confirmability aspects of the research study's trust worthiness were achieved. Thematic and NVivo analyses were conducted for analysing the collected data and ethical considerations for this study were also addressed.

CHAPTER 5

FINDINGS AND DISCUSSION

5.1 Introduction

This chapter gives a report and a discussion of the research study's findings based on the data data that was collected through face-to-face interviews and triangulated by document review. Thematic analysis was performed on the ten interview transcripts. NVivo analysis was then used to triangulate findings from the thematic analysis. This chapter also presents the proposed framework for implementing e-health interoperability in developing country contexts. The discussion of the study's findings is based on the objectives that guided this research study. These are to:

1. Determine the current status of e-health implementation in Zimbabwe;
2. Determine the current status of e-health interoperability in Zimbabwe;
3. Determine the barriers in the implementation of e-health interoperability in a developing country context;
4. Determine the enablers in the implementation of e-health interoperability in a developing country context;
5. Identify the consequences for the lack of e-health interoperability in a developing country context;
6. Develop a framework for implementing e-health interoperability in the context of developing country.

The study's findings identified several health information systems such a Human Resources systems, Aggregate information systems, Laboratory Information systems, Administrative systems and HISs for HIV/AIDS. The maturity level of e-health systems implementation was reported to be low. The research findings furthermore showed that the status of e-health interoperability in Zimbabwe was at an early stage, just like in other developing countries. Four types of barriers or impediments to e-health interoperability were also revealed by the study namely, technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers. The findings also revealed several enablers to e-health interoperability in Zimbabwe that include the existence of a worldwide technical community supporting OpenHIE, the presence of NGOs such as HITRAC that are providing leadership and taking initiative; development of re-usable software components hence no need to reinvent the wheel; options of using cloud services to address a lack of infrastructure and skills as well as regional conformance testing as a strategy for promoting interoperability. The findings conditionally pointed out that the lack of interoperable health information could lead to the following effects: burden on the health worker, health records cannot be shared, wastage of resources, wastage of drugs and high cost of healthcare to the patient and the government. Using data collected through interviews, a dual framework for implementing e-health interoperability in Zimbabwe was developed.

Thematic analysis was used for analysing the interview transcripts, and was guided by the study's theoretical framework derived from Chen and Daclin's (2006) framework for enterprise interoperability.

5.2 Results of interviews

This section is a discussion of the interview results. Participants responded to interview questions that were aligned to the current status of e-health implementation in Zimbabwe (objective1), the current status of e-health interoperability in Zimbabwe (objective 2) and the consequences for the lack of e-health interoperability in a developing country context (objective 5). Findings from these interviews informed the development of a framework for the implementation of e-health interoperability in a developing country context (objective 6). The results are presented based on the objectives of this study. The themes that are discussed under each objective's findings were derived from the thematic analysis of the interview transcripts. These themes and their associated codes are shown in Table 4.2.

5.2.1 The current status of e-health implementation in Zimbabwe

Findings and discussions under this section are aligned to objective 1. Two major themes that emanated from interviewee responses were the types of Health Information Systems (HISs) and the maturity level of e-health systems implementation. The first interview question that was asked under this objective required respondents to identify the e-health systems used in Zimbabwe and to categorise them, hence the theme, types of Health Information systems. Responses from interviews with key informants were analysed using thematic analysis. Several HISs were identified including Human Resources systems, Laboratory Information systems, Administrative systems and HISs for HIV/AIDS. The second part of the first interview question also under objective 1 required respondents to give an assessment of the level of maturity of e-health systems implementation in Zimbabwe. The maturity level of e-health systems implementation was reported to be low. Hence those two themes emerged under objective 1. The types of Health Information Systems (HISs) implemented in Zimbabwe are presented below followed by a discussion on the maturity level of e-health systems implementation.

5.2.1.1 Types of Health Information Systems

Health Information Systems for HIV/AIDS

The thematic analysis revealed that there were several information systems used for monitoring HIV/AIDS patients in Zimbabwe. These were Electronic Patient Management System (ePMS), Electronic Point of Care (ePOC) and HIV macro database. Participant 8, explained that:

> *"We have a system called electronic Patient Management System. So, this system allows information that has been captured onto papers or onto registers to be captured into an electronic system in an effort to track all HIV positive people whether they are still taking the medication properly and stuff like that".*

The thematic analysis revealed that 70% of the participants (Participants 1, 2, 3, 5, 6, 7 and 8) mentioned Health Information Systems for HIV/AIDS. Participant 1 state that:

> *"We have what is called ePMS, electronic Patient Management System, this system is currently managing HIV/AIDS data in the country. I think this is being supported in about 680 sites in the country".*

Participant 2 concurred that:

> *"... EPMS (Electronic Patient Monitoring System) which is specific to ART or HIV*

program. So, they would monitor any client who is enrolled to the program and then across the program until you know the outcome, whether the person dies or is transferred to another area."

Similarly. Participant 3articulated that:

Then there is the ePMS implementation".

Participant 5 contends that in terms of Health Information Systems for HIV/AIDS:

"In our public sector there is ePMS for HIV specific".

On the same note, Participant 6 explained that:

"Then we also have program level systems which are being used throughout the country like EPMS which is targeted towards HIV and TB patients".

Participant 7 concurred with the following input:

"There is also one called ePOC funded by UNDP specialist clinics and government hospitals. Systems that address TB and HIV/AIDS".

Participant 8's response on this matter was:

"Then we also had a system that was focused on managing HIV data, in fact managing patients who are on Anti-Retro Viral Treatment. We have a system, Patient Management System".

Participant 8 also explained the role of the HIV/AIDS system saying:

"So, this system allows information that has been captured onto papers or onto registers to be captured into an electronic system in an effort to track all HIV

positive people whether they are still taking the medication properly and stuff like that".

These findings on the use of health information systems to monitor HIV/AIDS patients is consistent with literature as evidenced by Gumede-Moyo, Todd, Bond, Mee & Filteau (2019) where a Zambian EHR, SmartCare was used to improve the prevention of mother-to-child transmission (PMTCT) data collection to enable the use of Smartcare for clinic performance strengthening and program monitoring.

Malawi also runs an antiretroviral therapy (ART) Electronic Medical Record (EMR) system that tracks patient access to and retention on ART. In addition, the system ensures efficient drug forecasting and timely procurement to avoid drug stock-outs (Douglas et al., 2010). A Point of Care (POC) touchscreen EMR system was introduced in Malawi with the aim of supporting and monitoring the scale-up of antiretroviral therapy. The ART clinic at Queen Elizabeth Central Hospital (QECH) in Blantyre is where the pilot implementation of this system started in 2006 (Douglas et al, 2010). The POC touchscreen EMR system is targeted for the high-burden ART sites in Malawi just like ePMS runs in high volume ART sites in Zimbabwe.

<u>Administrative systems</u>

Administrative systems are information systems that support the administrative functions of a health facility in Zimbabwe. However, these systems do not serve any clinical or medical purpose but serve an administration role. Such administrative hospital support functions include accounting and financial management, patient admissions, human resources and patient bookings. The thematic analysis showed that 60% of the participants (1, 2, 3, 4, 7 and

8) highlighted various Administrative systems and showed that participants were aware of some of the support information systems used in the context of health care in Zimbabwe.
From the thematic analysis, several Administrative systems were identified, namely: Human Resources Information System (HRIS), Practice Management Information system, Public Finance Management System (PFMS), SAP Healthcare system and In-patient Morbidity and Mortality Information System (IMMIS).

According to Participant 2 the HRIS is used for registering all employees in the public medical facilities. Participant 2 said: *"It is where every Ministry of Health worker is registered".* Participant 2 further elaborated that:

> *"This is mainly to do with the public sector, but when you move into the private sector there are now associations, the councils that register their own specific workforce*".

Moucheraud et al (2017) note that the Health Informatics Training and Research Advancement Centre (HITRAC) based at the University of Zimbabwe, developed and deployed the HRIS, which was launched in 2009. the Ministry of Health and Child Care (MoHCC) and several other national professional regulatory councils use the HRIS by to collect, store, analyse and report on the health workforce's demographics, training needs, deployment and migration patterns. Moucheraud et al (2017) concurred that the HRIS is an integrated and interoperable system that is meant to produce accurate health workforce surveillance information useful for tracking the health workforce as well as for decision-making. Although Participant 1 said HRIS is employed in the public sector, Moucheraud et al. (2017), contrarily posit that HRIS is employed in both state-owned institutions and private enterprises for the analysis of training, employment and demographics matters of employees in healthcare.

Many Sub-Saharan African countries are characterised by a shortage in the health workforce. This shortage hinders their health systems from providing adequate healthcare. There are several cases that suggest a wide implementation of information systems that manage human resources in Africa's healthcare institutions. As an example, the Health Ministry in Tanzania pioneered the development of a nationwide Human Resources for Health Information System (HRHIS) to address issues concerned with the supply and status of health workers in the country. The HRHIS was a coordinated and centralised information system that was useful for national planning, projection and forecasting of health workforce. (Japan International Cooperation Agency, 2011)

In Kenya, the government introduced the Kenya Health Workforce Health Information System (KHWIS) in 2002 whose aim was to "facilitate deployment of the right health workers (qualifications, skills mix) in the right place (deployment location) at the right time (availability)" (Courtney, 2013 in Waters 2013:896). Key components of the KHWIS included nurses' deployment, in-service specialties and upgrades, registration and licensing amongst others.

The Public Finance Management System (PFMS) serves the financial role, as echoed by Participant 2 that:

> *"This is a government-wide software, which we're actually using for support …We cannot overlook the need for a system that will be able to do the costing etc".*

Muzvidzi (2013) elaborates that the Public Finance Management System (PFMS) is a nationwide government system whose aim is to control, monitor and supervise the management of public funds. The PFMS connects all the Zimbabwean government line ministries to its parent ministry, the Ministry of Finance and Economic Development and is the sole system that processes all receipts and expenditures. It was introduced in 1997 to overcome challenges associated with budget formulation and weak internal controls and the training of end users (Muzvidzi, 2013). Accordingly, the PFMS is therefore used by the Ministry of Health and Child Care for its financial activities including budgeting, receipts and expenditure. Chawurura et al (2019) perceive this as an e-government initiative in Zimbabwe.

In the context of electronic financial management in healthcare, Hamad (2019) reported that Tanzania implemented a Health Management Information System (HMIS) with a billing and revenue collection module amongst other modules. This indicates that financial management is pertinent in the operations of health facilities. In the case of Ghana, the Ghana Integrated Financial Management Information System (GIFMIS) was launched in 2014 (CABRI, n.d.). The GIFMIS runs in all Ministries and entities that are financed by the national budget, such as hospitals, government-funded schools and municipalities. The system is used to monitor revenue collection, monitor disbursement and utilisation of revenue funds generated within government ministries and entities as well as to prevent fraud (CABRI, n.d.). The role of the GIFMIS was consistent with that of Zimbabwe's Public Finance Management System in that the system was not limited to the health ministry only, but it was also used in other government Ministries and entities.

Practice Management Information systems are systems used by different medical practitioners in private practice such as General Practitioners, specialist doctors, and even emergency rooms.

Participant 3 explained that:

> *"We have our own in-house developed custom solutions including practice management systems. So, the first one is what we call HMS (Hospital Management System). So, this runs from your GP to specialist to your ER up to hospital".*

The In-patient Morbidity and Mortality Information System (IMMIS) was the other administrative system that was mentioned. IMMIS was used for recording the number of patients admitted, condition that led to admission, number of days admitted, date of discharge from hospital and also the number of deaths in public hospitals. Participant 4 elaborated that:

"The other one is IMMIS (In-Patient Morbidity and Mortality Information System), which concentrates on the in-patients. It records the date they were admitted, the conditions why they were admitted, and when they were discharged. This helps in establishing workflow, in-patients and number of bed days. The bed days that is the length of time that they stay, and the conditions why they were admitted."

Participant 4 was the only participant who identified the IMMIS system. This could have been due to the fact that Participant 4 was one of the developers for the national EHR system, therefore he could have had a deeper insight into all the other public information systems that would be related with the EHR system.

The SAP Healthcare system was another administrative system identified by Participant 7. In terms of the SAP Healthcare system, Participant 7 said:

"There's also the SAP healthcare system which is being used at Chitungwiza hospital".

Participant 7 described the SAP healthcare system saying:

"*It's a complete health information system which has got ERP modules, that is enterprise resource planning, whereby it has the financial module, materials management, human resources, planning maintenance, payroll, costing and record management".*

Participant 7 also revealed that the SAP's merit was that it was an integrated system that included patient health record and billing. He elaborated that:

> *"The advantage of the SAP system is that it has the integration points. Once a patient is created in the healthcare site, that patient is automatically created as a customer in the financial sector … So, all the invoicing will be done against that customer number. So, all these modules can communicate, and they are well integrated".*

In addition, Participant 7 highlighted that SAP could also be used for querying and reporting saying:

> *"Any data you may require is captured in real time, for example if you want to see number of patients that have come to the hospital by particular time, you can just log into the system, if you want to see how many people paid in this particular time, you just log into the system and get the data, rather than the other systems whereby you have to wait for end of day or week to see the reports".*

However, SAP was not interoperable with other electronic HISs such as ePOC or DHIS2 that were running in public health facilities. Instead, for the SAP, interfaces had to be developed to facilitate inter-system communications. Based on Participant 7's explanation, the SAP Healthcare System included a module for the patient health record:

> *"But, as for the SAP system we have the ISH (Industry Solution for Healthcare).*

This mainly focuses on patient management from the point of entry into the institution, to the point of discharge".

Participant 7 was the only participant who mentioned the SAP Healthcare system. This could have been because he was a Functional Consultant at one of the government hospitals where this system was first implemented.

The interoperability aspect of these administrative systems could not be established from literature on Health information systems in Zimbabwe. However, some of the administrative systems namely human resources management, billing and financial management correspond to those that are found in some Tanzanian hospital management systems namely, AfyaPro, Care2x and GoTHoMIS respectively (Peltola, 2019). In addition, these functions (human resources management, billing and financial management) are not stand alone systems as is the case for Zimbabwe, but for Tanzania these exist as modules within the hospital management system identified above.

Aggregate Information systems

These systems are used for creating aggregate reports at different reporting levels such as District level, provincial and national levels. The District Health Information System (DHIS2) was the only system identified by participants in this category. The thematic analysis performed using NVivo 12 software revealed that DHIS2 was the most prominent aggregate information system. Fifty percent of the participants (Participant 5, 4, 7, 8 and 6) identified DHIS2 as an aggregate system. According to Participant 8:

> *"DHIS2 is a national repository, it's a data management tool for managers …This is a system that is being used nationwide by every facility in this country, at least the public health sector … all the facilities in the country do report through DHIS2 for national reporting".*

In terms of functionality of DHIS2, the United Nations Development Programme (UNDP) (2014) agrees that this system, through its integrated reporting system, provides improved data management and analysis useful for monitoring and assessing programmes, hence bringing about knowledgeable decision-making. Participants also revealed that DHIS2 was only used in government/public health facilities. This means that the reports generated by DHIS2 were only based on data from government health facilities and hence did not include data from the private health facilities, hence the interoperability problem.

According to the UNDP (2014) Zimbabwe's DHIS2 consists of eleven integrated reporting systems including the mobile phone-based Frontline SMS messaging for weekly health facility reporting, facility registers as well as the tracking of expecting mothers in rural areas, using mobile means. The benefits of the DHIS2 system included improved timely and reliable health information leading to improved data analysis, improved informed decision-making and improved quality national forecasting. In addition, the reporting burden of health professionals was significantly reduced as a result of the integration of various reporting systems into the DHIS2, thus allowing these professionals to spend more time with patients (UNDP, 2014).

It was also noted by the UNDP (2014) that the DHIS2 system was also implemented and running in a number of developing countries such as Ghana, Palestine, Uganda, Tanzania, Sri Lanka, Kenya and Sudan (Dehnavieh et al.,2019). According to Dehnavieh et al (2019) the extensive adoption of DHIS2 is evidenced by its implementation in 30 different countries across four continents. The prevalent adoption of DHIS2 has been expedited by several features such as data visualising through various types of graphs, user access control, customised data entry, integrated GIS module as well as integrating the messaging system and DHIS2 mobile solution (Manjo et al. 2013, cited in Dehnavieh et al., 2019).

Laboratory Information Systems

According to Blaya et al. (2007), laboratory information systems ideally keep track of laboratory activities and assist in reporting laboratory results to healthcare professionals. The thematic analysis revealed that forty percent of the participants (participant 1, 3, 4 and 5) mentioned laboratory information systems. Among the four participants who identified Laboratory Information Systems, three of them (participant 2, 4 and 5) mentioned the Laboratory Information Management System (LIMS) and only one (participant 3) mentioned the Lab263 information system. The reason for this was that these 3 participants worked for government-related organisations and thus identified LIMS which is used in public health facilities. On the other hand, participant 3 worked for a private company and thus identified

Lab263 which is implemented in various private health facilities.

Sembajwe, Shamu, Machingura and Chidawanyika (2018) stipulate that LIMS was operating in six Zimbabwe's district laboratories, and was performing very well in terms of improving laboratory information management and improved timeliness of reporting. It was also reported that between 2013 and 2017, the use of LIMS resulted in a notable reduction of turn-around time to obtain clinical results (from 10 to 21 days in 2013 to only 3 days in 2017). The number of untested clinical samples dropped from an average of 6 in 100 (6%) in 2013 to an average of less than or equal to 1 in 100 (1%) in 2017 (Sembajwe et al., 2018). Also, there was increased clinician satisfaction consequently resulting in the demand for the implementation of LIMS in more laboratories (Sembajwe et al., 2018).

With respect to software licensing, LIMS was open source and was customised to Zimbabwe's preferences whilst Lab 263 was a proprietary software. Participant 3, who works for a private company that developed Lab263 said:

> *"Then we have also done a Lab information management system …Yes, it is something that we built from scratch, called Lab 263".*

It was noted that one of the reasons why Zimbabwe's Health Ministry chose LIMS is because it is highly interoperable with other systems. Sembajwe et al. (2018) revealed that interoperability and community of practice support were some of the factors that were considered before LIMS was chosen and implemented. However, the systems that interoperate with LIMS were not specified.

<u>Logistics Information Systems</u>

A Logistics Management Information System (LMIS) is an organised system “for supporting storage, transportation, wastage reduction, forecasting, planning and avoiding stock-outs” (Bergum, Nielsen and Sæbø, 2017:2). Only 30% of the participants (Participant 1, 2 and 5) identified Logistics Management Information systems. A LMIS known as Navision was identified by Participants 1 and 2, whilst Participant 5 did not mention a specific LIMS however, highlighted that generic LMIS were also used in healthcare. The Navision system was said to be used by NatPharm (a subsidiary of the Ministry of Health and Child Care) for procuring and dispensing medicines and other medical supplies. In this regard, Participant 2 explained:

> *“There is a system called Navision. This is actually used by our warehouse (NatPharm is a subsidiary of Ministry of Health). It is used for procurement of medical commodities, medicines and sundries, and then dispensing to Provincial warehouses”.*

A well-functioning healthcare system is strengthened by an uninterrupted supply of health commodities, at the right time in the right quantities, thus making LMIS systems vital in health services (Bergum et al, 2017). The use of LMIS was also evident in other developing countries such as Tanzania where a Logistics Information Systems known as Epicor was used to address issues of stock availability and order forms among other functionalities (Bergum et al., 2017). This means that the use of logistics information systems in healthcare was not peculiar to Zimbabwe alone.

<u>Point of Care (PoC) systems</u>

Point of care systems are those utilised when providing healthcare services. The thematic analysis revealed that 50% of the participants (Participant 1, 2, 5, 6 and 8) mentioned Point of Care systems. Participant 2 described that:

> *"What I'm talking about is a point of care system, like, EHR (Electronic Health Record), the EMR (Electronic Medical Record) etc., so we call this point of care systems because you can only apply or utilize them as you're providing a service".*

The thematic analysis also showed that Electronic Health Record (EHR), also known as Impilo, was the Point of Care system identified by the 5 participants. According to the Health Information Management Systems Society (HIMSS) cited in Muñoz et. Al. (2011:1) Electronic Health Records are

> *" longitudinal records of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports*"

EHR is also a clinician system as observed by Participant 8 who said:

"… EHR is a clinician system. In other words, it's used by clinicians, a system used by doctors used by nurses when they are doing their work".

Although the EHR system had been piloted in some health facilities (i.e. all Harare city clinics and all health facilities in the Uzumba-Maramba-Pfungwe (UMP) district under the province, Mashonaland East in Zimbabwe), there were plans for it to be deployed nation-wide. Even though the national EHR is still being developed, it is already operational in Harare and the UMP districts. Participant 4 who was the lead programmer for this national EHR project stated that:

"The Electronic Health Record system is under continuous development (it is being used as we develop it), it is deployed in Harare and in UMP. They are using it as it is being developed… The approach is agile, which simply means that we do as we go. So right now, like I said, we are testing and actively developing it."

This study's findings revealed that the EHR system was still work in progress, with the system piloted in only 2 districts in Zimbabwe (UMP and Harare). According to TechZim (2021) the government has plans to roll out the EHR system, nationwide. 5 central hospitals, 7 hospitals at province level, 30 hospitals at district level and 384 clinics nationwide were targeted to deploy the national Electronic Health Record (EHR) system and full deployment was expected by December 2023.

Other developing countries, like Zimbabwe have also adopted EHR systems. Kenya implemented in its public healthcare facilities, an open source EHR system that interfaces with the following systems: District Health Information System (DHIS), Logistics management Information System (LMIS), Human Resources Information System (HRIS), Financial Management Information Systems (FMIS), Laboratory information System (LIS), Pharmacy Information System (PIS) and Community Health Services (CHS). The EHR system was designed to have a Health Information Exchange (HIE) for facilitating interoperability and the sharing of healthcare data among the different modules of the EHR inside the same healthcare facility and amongst hospitals within the same country (Muinga et al., 2018).

In Jamaica, an open-source EHR system known as GNU Health was implemented by the Ministry of Health. GNU Health uses an open-source ERP called Tryton to enable the running of administrative and back-end roles of a clinic or hospital, on top of the clinical modules (Paton and Muinga, 2018). Despite challenges facing e-heath implementation in developing countries, they have soldiered on, in order to benefit from the adoption of EHRs.

The Ministry of Health in Zambia, through financial assistance from the American Centre for Disease Control and Prevention (CDC) implemented a national EHR known as SmartCare. Gumede-Moyo, Todd, Bond & Filteau (2019) posit, SmartCare was developed in a bid to improve continuity of care, to provide timely maternal and child health data, for trend reporting, for malaria and tuberculosis interventions in public health and for enabling data analysis by clinicians and health officials. SmartCare is structured into main modules and submodules. The main modules include clinical, pharmacy, laboratories, logistics, monitoring and evaluation, inventory and continuity of care (Gumede-Moyo et al., 2019). Smartcards are issued to patients on their first consultation. When visiting a healthcare facility patients produce Smartcards containing all their treatment details and clinical information which can be retrieved at any SmartCare health facility.

On the other hand, in developed countries the implementation of EHR systems has been motivated by government arrangements whereby providers of healthcare have been reimbursed for the ICT expenses, provided they could prove that the EHR was useful in improving provision of healthcare or increased effectiveness (Paton & Muinga, 2018). As a result, numerous clinics and hospitals in the developed world now have running EHR systems whilst in the developing world EHR systems have been implemented in selected healthcare facilities. Developing countries are yet to experience this kind of support from their governments, as a way of promoting the implementation of EHR systems.

Pharmacy systems

Pharmacy systems are those information systems used to order, dispense or track medications. Only one participant identified a Pharmacy system in use. Participant 3 highlighted that:

> *"For pharmacy there is Dispense-ware (a Zimbabwean owned system), Profam (a South African owned), Windscripts (South African owned system). Dispense-ware is the only biggest in Zimbabwe".*

Participant 1 acknowledged the availability of pharmacy systems, but did not mention any specific information system in this category:

> *"Then Pharmacy systems they are almost everywhere. Numerous pharmacy systems. We`ve got quite a number of these out there mostly developed as ad-hoc systems".*

Participant 7 highlighted that, some systems like the SAP healthcare system had an integrated Pharmacy module:

> *"Trimed has a pharmacy functionality, SAP has pharmacy module."*

However, the pharmacy module for the SAP Healthcare system was not yet operational (in the government healthcare facilities that participant 7 was working with), at the time of this study, but will be activated in the second phase of the system's implementation. Participant 8 clarified that:

> *"It is being implemented, and falls under the Clinical solution which is the second phase of the implementation".*

This study's findings however could not ascertain the exact pharmacy systems used in either the public sector or the private sector.

The use of pharmacy information systems was not unique to Zimbabwe only. Pharmacy information systems were also used in other developing countries like Saudi Arabia for assisting pharmacists to manage medication services, increase their knowledge about medication utilisation, as well as improve financial management (Alanazi, Al Rabiah, Gadi, Househ & Al Dosari, 2018). However, in most African countries namely Zambia, South Africa and Botswana, the law requires that a pharmacy must be licensed for it to operate (Drame et al., 2019).

Radiology information systems

Picture Archiving and Communication System (PACS) is the radiology information system implemented in Zimbabwe. Alhajeri and Shah (2019) define PACS as a digital imaging and management system that is used in healthcare to electronically acquire, access, store, transmit and archive medical images. However, PACS is not a standalone software but, comes embedded in most modern x-ray machines. Participant 8 mentioned that:

> *"For radiology they have something called PACS that has been coming with most of our more modern x-ray machines".*

Participant 8 was the only one who mentioned the radiology information system. The reason could be that he had a lot of experience, about 20 years, developing health information systems in various capacities. PACS is also used in other developing countries namely South Africa and Nigeria. According to Abbas and Singh (2019) PACS has been used in South Africa's public hospitals with moderate success for over a decade now. On the contrary, in Nigeria PACS is only found in a few public teaching hospitals, in selected large specialist private hospitals as well as in private centres for radio-diagnostics (Idowu & Okedere, 2020). In addition, Idowu and Okedere (2020), maintain that numerous healthcare facilities do not have PACS nor any other radiology information systems in use.

In terms of health information systems implementation in Zimbabwe, the following types of systems were being used in healthcare: HIV/AIDS systems (ePMS, HIV macro database and ePOC); administrative systems (HRIS, Practice Management Information System, PFMS, SAP healthcare and IMMIS); aggregate systems (DHIS2); laboratory information systems (LIMS, Lab263); logistics information systems (Navision); point of care systems (EHR); pharmacy (Dispense ware) and radiology systems (PACS). This study's findings suggest that more electronic health information systems were identified by participants compared to those reported in literature. Masuku (2019) acknowledged the operation of the following electronic HIS in Zimbabwe: DHIS2, IMMIS, ePMS, Laboratory Management Information System, Rapid Disease Notification System (RDNS) and the HIV Information Management System. In addition to these systems Chawurura et al (2019) adds the PFMS. Furthermore, Chawurura et al (2019) acknowledged the existence of additional projects and experiments that the health Ministry together with its associates, were involved in namely the national EHR (its development and piloting), the notification of maternal deaths, the piloting of tele-health in the Manicaland province, the monitoring of clinical mentoring and the implementation of e-partograph.

The electronic health information systems (HIS) identified by this study's participants are aligned to those found in literature. According to Moucheraud et al. (2017) the following are some of the systems that constitute HIS: laboratory systems, disease surveillance systems, district level routine information systems and human resource management information system. Malawi is also using almost the same HIS as those revealed by this study's respondents. According to Pankomera and van Greunen (2020) Malawi has two major information systems namely the national integrated Health Management Information System (HMIS) and the District Health Information System which is web-based and running in all the 28 districts in Malawi. The integrated HMIS is composed of the following subsystems: Human Resource Management Information System (HRMIS), Logistics and Supply Management Information System (LMIS), Financial Management Information System (FMIS) and the Physical Assets Management (PAMIS) (Pankomera & van Greunen, 2020). The Malawi set up is slightly different in that they have an integrated system (HMIS) that incorporates several HISs unlike the Zimbabwean scenario that is characterised by several standalone information systems for health.

In Uganda's case, two health information systems are in use namely DHIS2 and an Electronic Medical Record System (EMR) used for improving clinical inefficiencies and for reducing missed appointments. However, it appears Uganda implemented more of m-health applications, unlike Zimbabwe which has the mobile phone-based Rapid Disease Notification System (RDNS) only. The following are mobile-health implementations in Uganda: "Matibabu" for conducting a non-invasive malaria test and eliminating the need for one to visit a medical laboratory to have a blood sample drawn; mTrac (mobile tracking) for reporting on disease surveillance and for medicine tracking in Uganda's 5000 health facilities and "WinSenga" for monitoring the heart rate of the fetus using a smart phone (Kiberu, Mars & Scott, 2017).

5.2.1.2 Maturity level of e-health systems implementation in Zimbabwe

Findings and discussions under this section are aligned to objective 1. The second question on the interview guide sought the interviewees' assessment of the level of maturity of e-health systems implementation in Zimbabwe. The maturity level of e-health systems implementation refers to the progression of e-health systems implementation from low level to advanced level. In this context it also refers to the scaling up of pilot e-health projects or systems to proper information systems with a wider coverage or even national coverage (a HIS that runs nationwide). Based on the interviewees' responses, it could be said that the respondents' perspective of the maturity level of e-health systems implementation was based on the extent to which e-health systems were being used in the country, contrary to this study's intended meaning. Findings from the key informants suggested that the maturity level of e-health systems implementation was low. Thematic analysis showed that 80% of the respondents (Participant 1, 2, 3, 4, 5, 6, 7 and 8) agreed that the maturity level of e-health systems implementation in Zimbabwe was low. Participant 1 highlighted that:

"So that basic level of basic data entry and basic analytics, that is where we are".

Participant 3's judgement was:

> *"… with labs, radiology, and practice some are still manual, I would rank these around 30, in terms of uptake."*

Participant 4's comment was:

> *"And it's difficult to assess where we are because it still is in its infancy."*

Participant 5's rating in this regard was:

"We're at 40% (4/10), being that we have a lot of systems, but we're not even using any of the systems to their maximum potential".

Participant 6's assessment was:

"Zimbabwe is still a little bit far … I would give it a three (3)". This was 3 out of 10.

Participant 7's comment was:

"We still have got a long way to go … I can rate it as 3". This was also 3 out of 10.

On the same note Participant 8's assessment was:

"At the moment low, very low. Very low might not be the right word, but its low".

Thus, it could be said that Zimbabwe's maturity level of e-health systems implementation was generally low. On the contrary, only Participant 2 rated the country's maturity level of e-health systems as above average saying:

"We are not doing very well but we are in the right direction. I would rate it around 6, just above average. The potential is there but we have issues to do with governance, governance documents and governance structures".

The reason could be that Participant 2 was privy to other e-health initiatives which might not have been known by other participants, since he held a highly ranked position in the Ministry of Health and was responsible for Health Information Systems (HIS).

Participant 8 expressed the maturity level of HIS in terms of their ability to interoperate. According to Participant 8, there were only 3 electronic HISs, namely, DHIS2, LIMS and EHR, running in the majority of public health facilities that had capacity to interoperate. He stated:

> *"So, you find that these systems, DHIS, the LIMS and EHR; the way they have been designed from bottom up, they have been designed so that they can accommodate interoperability…But because these are the national systems, one of the requirements is that they should be able to interoperate. Those three systems will interoperate … so that's by design".*

Based on Participant 8's comment, it appears that there were plans to have the HISs interoperate at national level despite the e-health systems implementation and maturity being low. In addition, according to participant 8, another way of describing the maturity level of e-health systems implementation was to consider the geographic coverage of such systems. Participant 8 further elaborated that:

> *"Had it not been for these national systems we are talking about, we could still be talking about a small system here, a private pharmacy having their own system but there is no way these people could talk to each other".*

The low maturity of e-health implementation in Zimbabwe that was revealed by this study is consistent with literature. In agreement with the country's low maturity of e-health implementation, Chawurura et al (2019) acknowledged that Zimbabwe had three electronic health information systems that were operated by the Ministry of Health and Child Care. These are the District Health Information System (DHIS2) for reporting accumulated health information, the electronic Patient Management System (ePMS) for monitoring HIV patients on Antiretroviral Treatment (ART) and the last one is the Public Finance Management System (PFMS) which is used to control, monitor and supervise public funds (in healthcare, in this case). In addition to these three, is the Laboratory Information Management System (LIMS) which runs in selected medical laboratories and is used for managing laboratory test results including feedback and distribution (Chawurura et al, 2019).

In terms of nationwide HISs, several African countries appear to have very few of that magnitude. In the case of Zambia, Gumede-Moyo (2019) assert that in 2010, SmartCare became a national EHR and was at that point rolled out nationwide. According to Mwanza (2019) by the year 2017 SmartCare was deployed in 856 health facilities comprising of public, private, military clinics and hospitals in 10 provinces and 103 districts. In South Africa, the National Department of Health (NDOH) in 2014, launched a national scale m-health system, MomConnect, targeted to improve maternal health and enhance antenatal services on a nationwide scale. MomConnect uses mobile phones to register pregnant women in South Africa, as well as communicate with them stage-based maternal-related messages while they are pregnant right through to after they deliver their babies. The system has 3 major features namely the registration of pregnant women into a national pregnancy registry, informative text messages that are sent weekly and finally a helpdesk that is interactive (Jahan, 2020)

In conclusion, for objective 1 that sought to determine the current status of e-health implementation in Zimbabwe the major findings were two-fold namely: the types of Health Information Systems (HISs) in use as well as the maturity level of e-health systems implementation. In terms of health information systems implementation in Zimbabwe, the following types of systems were being used in healthcare: HIV/AIDS systems (ePMS, HIV macro database and ePOC); administrative systems (HRIS, Practice Management Information System, PFMS, SAP healthcare and IMMIS); aggregate systems (DHIS2); laboratory information systems (LIMS, Lab263); logistics information systems (Navision); point of care systems (EHR); pharmacy systems (Dispense ware) and radiology systems (PACS). The types of HISs operating in Zimbabwe were found to be similar to those in other African countries such as Malawi and Uganda. As far as the maturity level of e-health systems implementation is concerned, the research findings established that it is low and this is consistent with literature.

5.2.2 The current status of e-health interoperability in Zimbabwe

The findings and discussions under this section are aligned to objective 2. This objective was addressed in three parts namely, the status of e-health interoperability in Zimbabwe, interoperability barriers and interoperability approaches. For this objective, results were presented in terms of Chen and Daclin's (2006) Framework for Enterprise Interoperability (FEI) which formed the basis of this study's theoretical framework. The FEI outlines interoperability concepts which were adopted in this study. In the context of this study, the FEI consists of interoperability barriers and interoperability approaches. First, were participants' views pertaining the overall status of e-health interoperability in Zimbabwe. Second, was a discussion of the status of e-health interoperability in terms of the interoperability barriers namely, technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers as defined by this study's conceptual framework. Third and final is a discussion on interoperability approaches as methods of addressing the interoperability barriers.

5.2.2.1 Overall status of e-health interoperability in Zimbabwe

About 60% of the respondents concurred that Zimbabwe is characterised by a low level of e-health interoperability. Thematic analysis performed on the interview transcripts revealed that overally, the status of e-health interoperability in Zimbabwe was low. On this matter, participant 2 commented that: *"out of 10 we are very, very far"*. On the same note, participant 7 observed that:

> *"Most of the systems are working in isolation, there is a need for those providers to work hand in hand, to have a proper interface".*

That the status of e-health interoperability is low in Zimbabwe is consistent with the situation in other African countries. For instance, in Tanzania it was reported that close to 86% of the health information systems were not interoperable (Kajirunga & Kalegele, 2015). In Botswana Ndlovu et al. (2021) also observed m-health applications and e-record systems were fragmented and thus not interoperable.

Responding to the question on the status of e-health interoperability in Zimbabwe, Participant 5 said:

"There is no recognised architecture for health information exchange. I have been around since 2016… This EHR has got its own architecture… its' own registries ...".

This could imply that the adoption/use of a recognised architecture for Health Information Exchange was a sign of higher level of e-health interoperability while a lack thereof is a sign of low level of e-health interoperability. Crichton, Moodley, Pillay, Gakuba & Seebregts (2013) state that in Rwanda, the interoperability of disparate health information systems is being facilitated by a Health Information Exchange, the Rwandan Health Information Exchange (RHIE). The overall architecture of the RHIE is founded on the Open Health Information Exchange (OpenHIE), an open source structural design (architecture) for implementing e-health interoperability in resource-constrained environments. The initial phase of the RHIE focused on two point of care systems namely an Electronic Medical Record (EMR) system (an implementation of the OpenMRS) and an SMS based data collection application (an implementation of RapidSMS) used by community health workers. The architecture of the RHIE's interoperability layer is implemented via an open-source Health Information Mediator (HIM) using an Enterprise Service Bus (ESB) approach. The success of the Rwandan HIM architecture in 2010 consequently served as the motivation to have it function as the Open Health Information Mediator (OpenHIM) which is a reference technology for the interoperability layer for the OpenHIE architecture (Crichton et al., 2013). OpenHIM is currently maintained by Jembi health systems a non-profit organisation considered as one of the leading specialist HIS organization in Africa that focuses on the development of health information systems. Jembi health systems has core proficiencies in enterprise and systems architecture for healthcare as well as competencies in analysis, design and the development of health systems software.

However, since the national EHR system was being developed locally (in Zimbabwe), some respondents expressed the status of e-health interoperability in terms of which HISs could interoperate with the national EHR. Participant 2 highlighted that:

> *"EHR and DHIS-2 can communicate at this stage".*

Participant 5 agreed that:

> "*It (EHR) can interoperate with DHIS2" … "It (EHR) can integrate with EPMS"*.

This demonstrated that e-health interoperability is steadily progressing, considering that the EHR, DHIS2 and ePMS, the country's major electronic HISs were already interconnected.

Efforts were made to find out how the findings about low level of interoperability concurred or diverged from findings on e-health interoperability in other developing countries. In order to accomplish this task, the status of e-health interoperability in Zimbabwe was compared to that of other developing countries in Africa. For instance, the Rwandan and Tanzanian experiences demonstrated that Zimbabwe was lagging behind in terms of e-health interoperability. In comparison with Rwanda, the status of e-health interoperability in Zimbabwe was found to be lower. According to Crichton et al. (2013), Rwanda has a functional Health Information Exchange, the Rwandan Health Information Exchange (RHIE) that enables point of care systems already implemented in Rwanda to connect and interoperate. This development was also known as the Rwanda Health Enterprise Architecture (RHEA) project. Rwanda's Ministry of Health with support from its partners such as Jembi health systems, IntraHealth International, Innovative Support for Emergencies and the Regenstrief Institute, developed the RHIE in 2010. Key components of the RHIE were the national shared health record and an interoperability layer (Rwandan HIM) whose role is to make patient medical histories more readily available to healthcare providers so that they can provide better healthcare service (MEASURE, 2020). Rwanda had already achieved all this by 2010, yet in 2022 Zimbabwe had no Health Information Exchange in place, was still developing its national Electronic Health Record and still working on its interoperability layer.

In order to effectively execute its e-health agenda, the Government of Rwanda also established an eHealth department whose mission was to provide and maintain reliable and secure information systems in order to provide improved healthcare services (Gakuba, 2009 in MEASURE Evaluation, 2020). Rwanda also has some key guiding documents that lay out the goals, strategies and policies for eHealth in the country. These include the Health Sector Strategic Plan IV (2018–2024) and the National Digital Health Strategic Plan (2018–2023) which was in draft form in 2020.

Karijunga and Kalegele (2015) posit that several health information systems in Tanzania lacked interoperability and focused on collecting, managing and analysing data. According to Dwivedi et al. (2021) Tanzania implemented the Tanzania Health Information Exchange (Tz-HIE) in 2019 which is currently enabling electronic health data exchange among 15 disparate health information systems. This was made possible by the partnership between the Tanzania's Health Ministry known as the Ministry of Health, Community Development, Gender, Elderly and Children (MOHCDGEC) and USAID's Maternal and Child Survival Program (MCSP) flagship that developed an interoperable HIS which enables data exchange through an interoperability layer. Tanzania's HIE architecture was implemented using the Asia eHealth Information Network (AeHIN) and not the OpenHIE as in the case of Rwanda. In the case of Tanzania, the interoperability layer was implemented through the HEALTHeLINK tool version 3 as opposed to the OpenHIM used for the OpenHIE architecture. In addition, the Tz-HIE also adopted some international data standards for data exchange. These are the ICD10 for standardizing data on disease and death and the Current Procedure Terminology (CPT) codes for medical services. Examples of the latter (CPT codes) are: CPT codes 10021 – 6990 for surgery and 80047-89398 for pathology and laboratory. In the Zimbabwean case, the ICD10 is also used for uniquely coding diseases (Ministry of Health and Child Care, 2020).

This research study revealed that e-health interoperability was still at a low level. This concurred with the documented status in other Low Resource Countries (LRC) in Africa. Stroetmann (2019) stated that health information in developing countries is siloed lacks interoperability and integration. In the case of Uganda, Kiberu et al. (2017) reported that, the national e-health policy for Uganda (2013) indicates that a great number of e-health applications were operating in silos and could not share information due to lack of interoperability and compatibility.

In Kenya, a study that assessed HIS interoperability readiness was conducted using the Health Information Systems Interoperability Maturity model developed by Monitoring and Evaluation to Assess and Use Results (MEASURE) Evaluation (Nyangena et al., 2021). According to Nyangena et al. (2021) e-health stakeholder representatives mostly from the Health Ministry's Digital Health Technical Working Group conducted the assessment. The assessment instrument concentrated on three main areas namely leadership and governance, followed by human resources and finally technology. The findings revealed that the majority of the HIS interoperability maturity model domains and sub-domains satisfied the nascent or emerging stages, which are the two lowest maturity levels. The nascent level is characterised by isolated and ad-hoc systems. At the emerging stage, systems are defined by processes and structures, although they lack ongoing monitoring exercises and are not documented systematically (Nyangena et al., 2021). Nyangena et al., (2021) also revealed that these findings were similar to findings from the HIS interoperability maturity assessment performed in Ghana and Uganda.

Ndlovu et al. (2021) pointed out that in Botswana, the health information systems lacked interoperability within the public sector as well as between public and private sector electronic health information systems. The electronic health information systems landscape was also characterised by manual data sharing, duplication of efforts across e-records systems as well as reporting systems that did not follow standardised processes. Consequently, all these resulted in problems to do with loss of patient information and confidentiality. In addition, several m-health initiatives were also implemented in Botswana in a bid to promote priority healthcare programs, but however these initiatives were not sustained. Moreover, during their existence, these m-health applications operated in silos without being connected/linked to the e-records system in Botswana. This lack of interoperability played a part in its demise (Ndlovu et al, 2021).

5.2.2.2 Interoperability barriers

In accordance with the Framework for Enterprise Interoperability by Chen and Daclin (2006), this research study implemented a barrier-driven approach. The word barrier here implies an incompatibility or inappropriateness or mismatch that is an impediment to the exchange or sharing of information. In accordance with this study's theoretical framework which is based on the Framework for Enterprise Interoperability by Chen and Daclin (2006), four classes of barriers (obstructions) to interoperability were adopted namely: technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers. This research study's findings for objective 2 are presented under these barriers as sub-headings. Table 4.2 shows how the themes were derived from the associated numerous codes.

5.2.2.2.1 Technological barriers

Technological barriers are those that are centered on ICT or the use of computers for exchanging information. Examples of technological barriers hindering interoperability are operating systems, infrastructure as well as incompatibilities of IT infrastructure and platforms (Chen and Daclin, 2010). Standards to present, process, store, exchange and communicate data (using operating systems and middleware) constitute the technological perspective for interoperability, according to Chen and Daclin's (2010) Framework for Enterprise Interoperability.

However, 60% of the participants (participant 1, 2, 3, 4, 5 and 8) did not consider technological factors from an interoperability perspective since they highlighted issues to do with internet availability and cost of connectivity. Only 2 participants (participant 6 and 7) contributed technological barriers from an interoperability viewpoint. Participant 6 revealed that point-to-point integration was being used to connect certain systems. Point-to-point integration refers to the use of custom software to connect ideally, two applications. It is simple and can be easily implemented. However, it is not scalable since its efficiency deteriorates as more applications are integrated. With point-to-point integration the number of integration points exponentially increases as more systems are integrated and this consequently results in tight coupling among the systems (Lin, 2005). Participant 6 highlighted that:

> *"We currently don't have e-health interoperability. We have point to point integration but not interoperability".*

Participant 6 further elaborated that:

> *"It is not being done on a national level, so currently it's point-to-point so if you want your own system at Newlands clinic to speak to DHIS, you develop something to speak to that. There is currently no framework at a national level".*

Responding to whether SAP Healthcare System could talk to DHIS, Participant 7 said:

> *"Interfaces is possible but presently they are not communicating* **...** *We are*

currently working on the interface of SAP and DHIS, it is work in progress".

The absence of communications standards or incompatibility of protocols for data exchange might have resulted in health organisations exchanging data using methods described by Participant 6 and participant 7.

5.2.2.2.2 Organisational barriers

Based on Chen and Daclin's (2010) framework for Enterprise Interoperability incompatibilities of organisational structure and management styles used in different enterprises constitute organisational barriers. In order for two systems to interoperate, the authority and responsibilities of members in these organisations should be clearly defined. Authority delimits what individuals are authorised to do, for example, who is authorized to create, modify and maintain data in a database while responsibility defines who is responsible for what, for example, who is responsible for data, software or computer hardware (Chen and Daclin, 2010).

Only participant 2 presented organisational barriers in the context of e-health interoperability. Participant 2 pointed out the challenges of unclear lines of command when he said:

> *"For example, I have my co-Deputy Director, who is in charge of ICT, but when you then look at his area of operation, there is going to be infringement into other spaces and the other way around. If those things can be set up to say, so people know where to start and there is harmonisation".*

Seitio-Kgokgwe, Gauld, Hill & Barnett (2015) agreed that the need to have precise duties and functions also emerged as a lessons amongst others, for establishing health information systems in Botswana and other developing countries. This demonstrated that the challenge of responsibilities and relationships as an organisational barrier was not only unique to Zimbabwe, but also existed in other developing countries. Participant 2's correct perception of organisational barriers to interoperability in Zimbabwe might have emanated from the fact that he is one of the Deputy Directors in the Health Ministry whose roles and responsibilities have been closely related to one of the Deputy Directors in the same Ministry.

5.2.2.2.3 Terminology barriers

According to Adebesin et al. (2013) terminology barriers are a crucial driver of e-health interoperability. Iroju et al. (2013) concurred that the absence of standardisation rendered the pursuit of high patient care and safety unsuccessful. Agreeing on the importance of standards, Participant 4 said:

> *"And then we talked about systems wanting to communicate with each other. The question would be how do they communicate? You can think HL7 or FHIR".*

Fast Healthcare Interoperability Resources (FHIR) is a more recent standard for exchanging healthcare information electronically (Luna et al., 2019). FHIR (pronounced as "fire") was developed by Health Level Seven (HL7) a standards development organisation for clinical data, and was developed after HL7 version 2 and HL7 version 3. Participant 9 also agreed that FHIR was an emerging standard for health information exchange, saying:

> *"So, in more recent years the focus has been on FHIR, and on HL7 FHIR as an emerging standard."*

Participant 9 further elaborated the suitability of the FHIR standard for use in developing countries or in settings where there are no standards as yet, saying:

> *"HL7 FHIR has more potential in Africa and Asia than it does in places like Europe and the US because they have already put together these giant, monolithic systems that are already using things like CDA; and to get them to change to something like FHIR is going to take more effort than something like here where you have these emerging ecosystems that don't yet have standards in place".*

Hence, both Participants 4 and 9 recommended the HL7 FHIR standard for e-health interoperability. The FHIR standard was also recommended for enabling the interoperability of m-health applications and e-records systems in Botswana (Ndlovu, Scott & Mars, 2021).

Participant 2 highlighted the need for cross country common standards and terminologies to ensure the continuity of care beyond borders when he said:

> *"There is no way you can talk of interoperability, without the standards. We need to go for standards that cut across other countries, we don't need to go for standards that only work in Zimbabwe. For example, Namibia and Botswana and Zimbabwe and South Africa relations, we have chronic patients on ART. What they may call a particular medicine here in Zimbabwe may not be the*

same just across the border. We would want to share the information across borders to ensure continuity of care beyond borders".

Hence, having interoperability standards that cut across borders is one way in which continuity of care can be achieved, especially for cross-border interoperability. This is buttressed by Hamad (2019) who proposed the creation of e-legislation to facilitate inter-jurisdictional practice of medicine as well as the exchange of healthcare data and patients. This would go a long way in making cross border interoperability a success.

Participant 5 observed that there seems to be no e-health standards implemented in Zimbabwe. In response to the question that required identifying semantic and syntactic barriers affecting the interoperability of e-health, participant 5 highlighted that:

"The absence of any stipulated semantic standards and syntactic standards. That's a huge gap…We have to adopt international standards as a country... We are not there as a country. We haven't identified any standards yet, as a country".

Responding to the question on the current status of e-health interoperability, Participant 5 said:

"There are claims that ePMS and DHIS are interoperable, I doubt it because there are no standards. If we had standards to say this is how we are going to

do it, you could easily go back to the standards and verify whether it's happening according to that".

This could mean that e-health systems developers could be developing software using different standards or using none at all. As far as terminology issues were concerned, Participant 8 lamented the lack of semantic standards:

> *"You find that our disease coding is standardised and coding for complains are all standardised. Most of them are based on international coding systems. So, where we are still lacking, is the semantic type of standards. We are still not there yet, but there are some standards that we already know like HL7, FHIR for health exchange. ICD10 is already being implemented. So, the standards are there, but they are not being fully implemented, there is still a lot of scope to cover".*

Participant 8 identified these standards since he is a seasoned programmer with over 20 years' experience in developing HISs. Ministry of Health and Child Care (2020) concurred that the following standards were already implemented in the national EHR system: standard for classification of diseases and conditions namely ICD10; standard for classification of patient complaints and health worker observations namely ICPC-2 and finally standards for classification of procedures namely CPT. Although standards are critical towards accomplishing interoperability in e-health, Khan (2013) in Stegemann and Gersch (2019) argue that usage of standards does not instantly guarantee interoperability, however, the coordination of workflows and the implementation are also other important determinants of e-health interoperability. Stegemann and Gersch (2019) further argue that lack of interoperability is more related to economic issues than to inadequate or absence of technical standards. Stegemann and Gersch (2019) maintain that there is a scarcity of clear incentives for healthcare providers to adopt interoperability. Thus, the absence of well-defined interoperability benefits to healthcare providers is an impediment to the adoption of interoperability in e-health.

5.2.2.2.4 Legal and regulatory barriers

Legal and regulatory barriers relate to issues of law and consequences of infringement as far as e-health is concerned. The thematic analysis revealed that 70% (7 out of 10) of the respondents mentioned legal and regulatory barriers. The sub-themes that emerged were: e-health strategy, governance, legal and regulatory issues, policy, legal statutes, professional bodies in healthcare and regulatory framework. Information gathered from interviewees suggested that the country's health system did not address legal and regulatory issues for e-health. Participant 6 highlighted that:

> *"The biggest challenge is that there is no standard framework for interoperability".*

In support of this, Participant 1 elaborated that:

> *"… we need a policy document, we need an e-health governance institution to actually regulate these issues of privacy, standards and ensuring that we meet the minimum interoperability requirements as defined by national and*

international standards".

The need for an e-health interoperability regulatory framework was also reiterated by participant 10 who said that:

> *"Interoperability is quite difficult without a regulatory framework. You can go a long way with people voluntarily conforming to an architecture but I think if you really want to get it entrenched in a country, you do need some kind of regulation".*

The document review carried out in this study revealed the existence of Government Acts, Bills, Policies and Charters associated with the provision of healthcare in Zimbabwe. These include the Health Professions Act Chapter 27:19 of 2000, Cyber Security and Data Protection Bill of 2019, Zimbabwe's National Policy for Information and Communication Technology (ICT) of 2016, Client Service Charter of 2012 and the Patients' Charter Zimbabwe of 1996. However, all these addressed health services in general and were not explicit in terms of e-health or e-health interoperability. Participant 5 agreed to this, revealing that:

> *"Although the National ICT policy is there, the country does not have an e-health policy".*

The lack of an e-health policy at national level implied the absence of harmonised and consolidated efforts towards e-health services. However, despite the absence of an e-health policy, the country had already implemented several HISs. Thus the lack of these regulatory statutes could have led to the current siloed systems and current difficulty for the government to control donor-funded HISs. Participant 2 explained that the e-health strategy has not yet been finalised:

> *"The fact that we don't have an e-health strategy. It also affects all this. We have a draft, what people thought would work, but it never came to life. Currently we are working on an e-health strategy but without that document there is always going to be discord".*

This was also supported by participant 1 who actually wrote the e-health strategy draft document in Zimbabwe, saying:

> *"But on a more focused approach, I wrote the first e-health strategy (2012-2017) for the Ministry of Health but it`s still a draft".*

The absence of an e-health strategy was also supported by the document review which confirmed that the country only had the "Zimbabwe's E-Health Strategy (Draft) 2012 -2017" in place. This was in contrast with other developing countries that had e-health strategies such as Malawi's "Malawi National eHealth Strategy 2011-2016", South Africa's "eHealth Strategy for South Africa 2012-2016" and Tanzania's "Tanzania National eHealth Strategy June 2013-July 2018". Although Zimbabwe did not have an e-health strategy, it had other national health planning documents such as the Zimbabwe Health Information System Strategy 2009-2014, National Health Strategy 2016-2020, Zimbabwe Electronic Health Record (EHR) Roadmap 2020-2023.

Concerning the Zimbabwe Health Information System Strategy 2009-2014, one of its objectives is to develop a framework for e-health and procedures to guide the MoHCC and its partners in terms of using ICTs for healthcare. Nevertheless, to date, the framework for e-health and the guidelines have not yet been developed. In addition, this strategic document is silent on e-health interoperability. The National Health Strategy 2016-2020, neither mentioned e-health nor e-health interoperability. With regards to the national Electronic Health Record (EHR) system, it was intended to be interoperable with other systems such as DHIS2. In addition, using the national EHR, application programming interfaces (APIs) would be available to enable the seamless exchange of data between the two systems. For instance, concerning Zimbabwe's national EHR system, specialized systems like the Laboratory information systems would require an API to enable it to connect to it. The national EHR's system architecture is founded on the Open Health Information Exchange (OpenHIE) architecture. This is an interoperability architecture that is maintained by the OpenHIE community of practice that focuses on providing a reference architecture and workflow specifications for sharing health information among point of care systems in resource constrained environments. With the OpenHIE data is stored and accessed from standardised repositories via an interoperability layer (Principles for Digital Development, n.d.).

In addition to an e-health regulatory framework, there is a need for measures to enforce conformance to law. Participant 10 proposed that there be a means of enforcing e-health interoperability legislation. The participant highlighted that in addition to the interoperability legislation it was important that there be associated means for enforceability. Participant 10 noted with concern that:

> *So, I think it's important to match regulation or legal frameworks with enforceability, as well as with the means for people to implement it... It's not really that much help to have a legal framework without enabling people to implement it".*

Participant 10 added that:

> *It's important to have that (legal framework), and to match that with training courses. And also have the compliance test or conformance testing. If you take those three pillars of it, you can have a very enabling environment for achieving interoperability, and you need all three of them.*

Participant 10 further proposed a maturity model for e-health interoperability when he said:

> *And you need to implement it in a good way, like maybe a maturity model is a good way to do that. So, you start off just providing guidance, like this is the architecture and it would be good for everyone if we subscribe to this, and you get people voluntarily doing it. And then you provide connectathons and hackathons, to provide people with a forum to test compliance to the standards in the framework. And then slowly over time, you have training courses to help people build their systems to match that. Then over time, you can make it more and more legally enforceable if you like. Then, that's your maturity model. So if*

you start off making it more a voluntary thing that people do, and they see the benefits, then down the line when it's part of the national infrastructure, and it's everywhere, and that's how you do things, then you can enforce it to something, any new technology would have to be conformed to those requirements".

According to Participant 10 having a regulatory framework is not enough to achieve interoperability, but relevant training as well as requirements to do conformance or compliance testing are also needed. The participant referred to these three: regulatory framework, relevant training and conformance testing as the "pillars of interoperability".

The use of regional conformance tests to ensure interoperability was proposed to enforce regulation on e-health interoperability. *Integrating the Healthcare Enterprise (IHE)* is an example of an organisation that could also be useful in setting up these conformance tests, such as the IHE connectathons. IHE is a standards development organisation that provides services and a testing environment for conformity assessment to promote interoperability amongst healthcare systems and devices (ITU, 2017).

These tests would be one way of ascertaining whether a given e-health system conforms to set standards and workflows. A connectathon, such as the IHE Connectathon, is an event that is centred on an open consensus-built interoperability specification. Its purpose is to provide vendors with an opportunity to assess the interoperability of their systems in a structured and thorough environment with peer vendors and developers (IHE, 2018).Participant 9 proposed that:

> *"I also mentioned IHE, there's an increasing move towards trying to set up regional conformance testing for interoperability. So, ways that are more attainable and easier to access for countries to say, listen, where we've worked towards an interoperability architecture, we wanted to kind of get a sign of, to say that it conforms to the standards and these workflows, etc. and setting up local and regional conformance and connectathon type avenues".*

Atalag, Kingsford, Paton and Warren (2010) concurred that any standard needs certain processes for regulating conformity to set standards. For example, in Australia the Australian health messaging laboratory provides a facility where developers can determine the level of conformity between their messages and the HLv2 standard.

This section presented the findings of this study in terms of the status of e-health interoperability and interoperability barriers. The outcomes of this study showed that the status of e-health interoperability in Zimbabwe was still at a low level. Technological, organisational, terminology as well as legal and regulatory barriers constitute the interoperability barriers. In terms of technological barriers, more than half of the participants did not mention technological barriers from an interoperability perspective. The absence of communications standards or incompatibility of protocols to exchange data might have resulted in the use of interfaces and point to point integration as the methods of exchanging healthcare data, according to this study's findings. With regards to organisational barriers, incompatibilities of organisational structure and management styles used in different enterprises constitute organisational barriers. Only one participant discussed organisational barriers in the context of e-health interoperability, namely, challenges of unclear lines of command. As far as terminology barriers are concerned it was gathered that some participants believed that certain standards have been implemented while others believed that none have been implemented. This could be dependent on the number of years of experience of the interviewee (participant) and where the interviewee worked before. Finally, with regards to legal and regulatory barriers, information gathered from interview key informants suggested that the country's health system did not address legal and regulatory issues for e-health, such as the need for an e-health interoperability regulatory framework. However, private healthcare providers fear that the easy interchange of health information due to interoperability, will enable patients to switch to other providers (competitors) thus resulting in no revenue generated from these patients (Stegemann and Gersch 2019).

5.2.2.3 Interoperability approaches

Interoperability approaches are methods that can help achieve interoperability between enterprise systems. Chen and Doumeingts (2004) as well as Chen and Daclin (2006) based on the ISO 14258:1998 standard for "Interoperability, integration, and architectures for enterprise systems and automation applications", posit that the general approaches to achieving system interoperability are the integrated approach, unified approach and federated approach. Turk (2020) concurs that according to the ISO 14258:1998 standard, the interoperability architectures for information systems are the federated, integrated and unified architectures. The integrated approach uses standard formats for all data models (Chen and Doumeingts, 2003). The unified approach requires a shared layout at a meta-level only and interoperating systems must have a pre-defined meta-model for semantic equivalence. Finally, the federated approach does not use any common format for interoperating systems. With the federated approach, there is dynamic accommodation and adjustment of the systems and this implies that systems must share an ontology.

In this research study the integrated approach was renamed “closely-coupled approach” and the unified approach was renamed “loosely-coupled approach”. This re-naming is consistent with Turk (2020) who asserts that the basic categorization of interoperable information systems is tightly coupled, loosely coupled and interfaced systems, which respectively correspond to the integrated, unified and federated interoperability approaches. The closely coupled approach is more oriented to the full integration of system modules or subsystems while the loosely coupled approach is more oriented to interoperability (Chen and Daclin 2010). In a loosely coupled approach, for systems to interoperate they simply map to the neutral meta format without having to change themselves (Chen and Daclin, 2010). According to Turk (2020) for loosely coupled systems to interoperate, only translations or mappings into a commonly shared structure or schema is required while a single schema shared by all the participating systems is required for closely coupled systems to interoperate.

In this study, participants advocated for a loosely coupled approach. This concurred with Chen and Daclin (2006) who stated that most research results in the interoperability domain, adopted the unified approach (loosely coupled approach). These findings are also consistent with Romero and Vernadat (2016) cited in Turk (2020), that the trend is towards developing more loosely coupled systems over pre-defined and rigid solutions (closely coupled systems). Loosely coupled systems promote rapid enterprise evolution and enhance e-business agility. However, not a single participant suggested neither the (integrated approach) closely coupled approach nor the federated approach. This was also consistent with Chen and Daclin (2006) who argued that it was generally difficult to achieve interoperability using the federated approach and that not much had been achieved using this approach.

Participant 9 proposed a loosely coupled approach through the OpenHIE by elaborating that:

> *"One of the key things with OpenHIE is that it provides an architecture, and is designed to be an architecture first and foremost. And from there, there are technologies, what are called reference technologies that can be used to solve some of those architectural components and problems. So, the overall architecture is looking at some standard standardized workflows, data standards*".

The OpenHIE architecture includes reference technologies or implementations which serve as examples of desired technological standards. However, with the open standards approach it means countries can choose to use other technologies as long as they stick to the overall framework. Some of the reference implementations of the OpenHIE architecture are Open Health Information Mediator (Open HIM) for the interoperability layer component; Open

Medical Record System (OpenMRS) for the shared health record component; District health Information System (DHIS2) an example of the Health Management Information System (HIMS) component and the Integrated Human Resources Information System (iHRIS) for the health worker registry component. This means different health information systems would be developed based on such an architecture (OpenHIE). The systems remain disparate but conforming to the same architecture to enable interoperability. The interoperability layer would allow heterogeneous systems to be incorporated into the OpenHIE and exchange information. Participating systems might require minimal changes but would maintain their local autonomy which are characteristics of a loosely coupled approach. Participant 5 implied the OpenHIE when he explained that:

> *"I know people like Jembi, they have done this nice architecture, you are supposed to look at your entity as an enterprise…this is how things interoperate, these are your standards. For me, that would be the first thing".*

Jembi Health Systems is a non-profit organisation that helps develop and maintain interoperable e-health solutions in developing communities such as Zimbabwe. Jembi Health systems belongs to the group of co-founders of the Open Health Information Exchange (OpenHIE) international community of practice. Jembi systems is in charge of the of the interoperability layer (implemented through the OpenHIM reference implementation) and the shared health record (implemented via the OpenMRS reference implementation) communities in addition to playing a role in the OpenHIE Implementer Network (OHIN) (Jembi

Health Systems, 2021). Jembi health systems advocates the use of open architectures such as OpenHIE to facilitate e-health inter-operability.

Participant 4 also agreed to a loosely coupled approach by suggesting the use of the OpenHIE architecture as a guideline to developing interoperable e-health solutions:

> *"If you go to OpenHIE website, there is a lot of documentation in terms of how to implement this kind of system and the only difference is the components you adopt or develop".*

The same sentiments were echoed by Stroetmann (2019: 406) who also advocated for the "open digital health platform" as being suitable to achieve interoperability in low resource communities, an example being Zimbabwe.

According to MEASURE Evaluation (2019), adequate skills and capacity building are important elements of interoperable HIS. In this context, Participant 10, responding to the question regarding the need for additional training to university graduates to qualify them to develop interoperable e-health systems, said:

> *"People coming out of university at the moment… will need quite a lot more knowledge to design interoperable solutions. I think both in terms of technologies like individual standards, even the functionality that are delivered by the components of a health information exchange, which is one of the major enablers of interoperability".*

This means that although there is a high number of IT university graduates in Zimbabwe (produced by Zimbabwean universities), it does not mean that there is availability of skilled manpower to implement interoperable HIS. Since Participant 10 referred to the Health Information Exchange (HIE) as “one of the major enablers of interoperability”, this implied the HIE is critical towards achieving interoperability. The proposed use of a (n) HIE towards the attainment of e-health interoperability is consistent with literature. An example is in Rwanda where the OpenHIE facilitated the interoperability of an Electronic Medical Record (EMR) system called the OpenMRS and an SMS based data collection application known as RaidSMS (Crichton et al 2013:88).

Summary

This objective was addressed in three parts. First, were the participants’ views concerning the status of e-health interoperability in Zimbabwe. Second, was a discussion of the status of e-health interoperability in terms of the interoperability barriers namely, technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers as defined by this study’s theoretical framework. The study revealed that the status of e-health interoperability in Zimbabwe was low. This was consistent with literature since low e-health interoperability was also reported in other African countries such as Botswana, Uganda, and Zambia. However, for Tanzania and Rwanda, although levels of interoperability were still low, these countries recorded some level of HIS interoperability through the use of health information exchanges namely the Rwandan HIE in Rwanda and the Tanzania Health Information Exchange (Tz-HIE). Third, was a discussion of interoperability approaches, which are methods of addressing the interoperability barriers. In this research study, most participants advocated for a loosely coupled approach over a closely coupled approach.

5.2.3 Consequences of a lack of e-health interoperability in a developing country context

Findings and discussions under this section are aligned to objective 5. In the interview guide question 11 asked respondents to identify the impacts of the lack of e-health interoperability. Thematic analysis performed on the interview responses showed that 7 participants mentioned various effects of a lack of e-health interoperability. The following effects emerged as the major consequences of a lack of interoperable e-health systems: burden on the health worker; records cannot be shared; wastage of resources; wastage of drugs and cost.

5.2.3.1 Burden on the health worker

Burden on the health worker is an effect cited by the respondents. Participant 2 explained that:

> *"I think it is a lot of burden on the health worker, of all the issues this is the most critical…Three quarters of the time is spent on papers (registers etc.) and not on people. If the interoperability layer is not there, it will create a lot of challenges. The same person will be registered more than 10 times even within the same facility, you register the same person in all these registers e.g. delivery register, chronic register, TB register. You register the same person in all these registers".*

From the conducted document review, it emerged that burden associated with the lack of interoperable systems on the health worker was also reiterated by Global Fund's Office of the

Inspector General (GFOIG) (2013:19) cited in Ministry of Health and Child Care (2020:13), Zimbabwe EHR Roadmap 2020-2023 that:

> "*Heavy staff work load (One example from our visits to two facilities showed that two nurses were expected to complete 19 registers in addition to the provision of health services)".*

The ripple consequence of this overwhelming need for capturing and recording data was an obstacle to the health workers' core duties of patient care and management.

Due to a lack of interoperable systems, there is redundancy when the same patient is registered more than once at the same facility and/or at the various health facilities that the patient visits. In terms of redundancy, the Ministry of Health and Child Care (2020: 14) Zimbabwe Electronic Health Record system (EHR) Roadmap 2020-2023 document concurs with this study's findings that:

> *"In many cases, data elements are being captured more than once into various tools that target specific data and information needs for individual programs and departments. This has resulted in some data discrepancies, whereby values for the same data element differ from source to source".*

Participant 3 echoed the same notion saying that:

> *"Without interoperability I think a lot of people are suffering. And it also makes doctors' lives difficult, because you are trying to diagnose a car as if it's the first time, and has not given any problems. When they are treating someone it's like they*

are brand new ….they have never fallen ill in their lifetime. You are starting from here. You are just making it difficult for the Doctors".

The ripple effect of such a scenario is organisational inefficiency. Responding to the question on effects of lack of interoperability, Participant 1 said: "*…organisational efficiency is totally affected. Resource utilization as well becomes wasted".* The document review conducted in this study also agreed with this aspect of "burden on the health worker", as a result of non-interoperable e-health systems.

The concern of burdening health workers was also elaborated by the Ministry of Health and Child Care (2020:13) Zimbabwe Electronic Health Record system (EHR) Roadmap 2020-2023 that states:

> *"… the nursing staff, who are the primary data collectors at the health-facility level, are overwhelmed by a plethora of registers, tally sheets, and monthly and quarterly reporting forms that they manage in conjunction with attending to patients. The resultant effect of these numerous registers and forms has made it difficult for nurses to give quality care to patients because more and more time is now being spent on making entries into registers and forms".*

Responding to the question on the effect of the absence of interoperability in e-health, Participant 3 contends:

> *"The first which is the biggest on my side is poor care. Eventually the patient suffers".*

In this regard it can be noted that the interview findings and the document review were in agreement that since health professionals were overwhelmed with entering data in numerous registers, this resulted in poor patient care.

5.2.3.2 Patient record cannot be shared

If a patient's medical history is scattered, then service delivery could be delayed or mis-informed because of the existing gaps. Participant 2 further elaborated on the effect of no interoperability in e-health, stating that:

> *"On the patient side, a total unavailability of the medical history of the patient, which will then support health service delivery*".

This may result in the need to repeat tests or procedures that might have been conducted earlier on by a previous medical practitioner. Participant 5 echoed the same sentiments that:

> *"Health records cannot be shared. Resource wastage due to redundancy and duplication. On the part of the patient, the records cannot be shared, you can only be seen at one facility, duplication of procedures".*

Duplication of procedures could usually require patients to pay again for those services, making it more expensive for them.

Participant 6 expressed difficulty of sharing health records also as an effect of a lack of interoperability, saying:

> *"A caregiver will not be able to know about a patient's previous record and*

diagnosis".

Sharing patient medical history is vital because it gives the medical practitioner background information useful for diagnosing and prescribing. Availability of patient medical history reduces or even eliminates issues to do with repeating procedures or prescribing drugs that the patient is allergic to. Participant 5 also echoed the same concern saying:

> *"Health records cannot be shared. On the part of the patient, the records cannot be shared...".*

Li, Clarke, Neves, Ashrafian & Darzi (2021) note that lack of interoperability in e-health results in the disintegration and fragmentation of patient information, thus patient data cannot be shared. Li et al (2021) concur that the inability to share patient records is one consequence of lack of interoperability in e-health.

5.2.3.3 Wastage of resources

A lack of interoperability also leads to wastage of resources, especially in terms of programming effort. Participant 8 elaborated that:

> *"Firstly, is wastage of resources. We spoke of ePOC and ePMS doing the same thing. EHR also has a module for that. So, if you think of these being developed by 3 different people, they are all developing the same thing for HIV. So, that's wastage of resources in terms of the resources that are required. So, lack of interoperability is resource wasteful".*

Instead of developing three different systems for the same goal as is the current situation, only one system could be developed and have the other programmers attend to other issues. Thus, programmer time and effort are wasted in this case, due to duplication of systems that perform the same functions.

The wastage of resources due to a lack of interoperability in e-health is consistent with literature. ITU (2017) reported that the wastage of digital health resources is among the effects of poor or a lack of interoperability in healthcare. ITU (2017) elaborates that different e-health projects with intersecting functionalities (but incompatible themselves) often consume grants from aid organisations, government resources or public funds, thus wasting such funds. This tallies with the concern raised by participant 8 that in the Zimbabwean case two different and non–interoperable systems (ePOC and ePMS) are being used for managing HIV/AIDS patients in the country. Participant 5 also concurred to resource wastage, but in terms of financial investment. Resource wastage because of the duplication of investment, was elaborated by Participant 5:

> *"From a financial perspective there is duplication of investment ... we have used our own architecture and our own interop layer and an investment in actual funds for the development process. Then the next guy is doing the same thing, it's an investment in that process".*

This duplication of investment can be eliminated by having interoperable e-health systems. ITU (2017) concur that non-interoperable systems especially vertical projects or systems result in a duplication of time and effort in most cases.

5.2.3.4 Wastage of drugs

Wastage of drugs is another consequence of non-interoperable e-health systems. Participant 8 elaborated that:

> *"It also reduces wastage of drugs. Some people can buy the same drugs so many times from different facilities with plans to re-sale or other purposes. When you have a system like an EHR, interoperability is working, people will be hindered from double purchases or collection of the same drugs".*

Wastage of drugs through double purchases or double collection is one challenge emanating from non-interoperable e-health systems. Participant 5 aired the same concern elaborating how an HIV patient registered at one facility would pretend to be a new case at another facility and register for ARVs collection again, thus making it possible for them to collect medication from more than one facilities within a month. Participant 5 said:

> *"…So, what happens is, the patient goes to Site A and pretends that they are new and at site B they are an old patient where they collect their month's supply. They go to site A and request to be tested. So, if you have your systems sharing data, because sometimes they go to private facilities or sometimes, they are just in the same public system using different solutions, or the same solutions, where the record is not shared…".*

This means, the same patient can collect medication from two facilities where they are registered. This can be eliminated by using interoperable systems. Participant 4 also shared the same concern, which he referred to as abuse of drug collection systems:

> *"Another example, patients themselves who are on care might abuse the system, for example, go to different facilities and collect medications. With a system you can track these sorts of things".*

This study's findings also showed that when e-health systems are not interoperable, patients with conditions like HIV or TB might abuse the drug collection system, thereby collecting the same drugs from more than one facility, resulting in abuse and wastage of drugs. Wastage of drugs due to non-interoperable health systems appeared not to be documented in literature. In addition, this consequence could have been peculiar to Zimbabwe due to the landscape of its health information systems.

5.2.3.5 Cost

There are additional costs that are experienced if records do not inter-operate. These costs can be because of the need to undergo certain tests (such as labs or radiology) that were done before but the results would be held up by a previous care giver. This becomes costly for the patient. Participant 3 revealed that:

> *"There is a lot of costs and inconvenience brought about by lack of e-heath interoperability".*

Participant 1 also agreed that when systems do not interoperate, certain processes are likely to be repeated (such as scans, x-ray), each time a patient visits a different medical facility, thereby increasing costs. Participant 1 explained that:

"Your costs are too high. Your costs are too high. That's one thing you have to look at. You will realise that you will repeat processes every time, in that process you will be increasing costs towards that service".

Cost as a consequence of lack of interoperability in e-heath is consistent with literature. Zeinali, Asosheh & Setareh (2016) highlight that the absence of interoperable e-health systems results in increased healthcare costs. Li et al (2021) add that lack of interoperability in e-health leads to additional healthcare expenditure. However, both these studies did not elaborate on the issue of increased costs.

If systems do not interoperate, certain processes are likely to be repeated (such as scans, x-ray), each time a patient visits a different medical facility, thereby increasing costs. On the same note, Participant 8 elaborated on how interoperable health information systems (HISs) save costs, saying:

"It cut costs. If you have had an x-ray yesterday and you are interoperable, the record would be viewed from any facility. So, it saves costs. It reduces repeat tests".

Thus e-health interoperability results in costs savings. Other consequences of non-interoperable health information systems that emerged from the research study were misdiagnosis, lack of software re-use, failure to track results of samples from laboratories, impeding innovation and inefficiency.

Medical errors are one effect of non-interoperable e-health systems that was not identified by interviewees but was discussed in literature. Zeinali et al. (2016) elaborated that based on statistics in 1999 in Iran, 98000 patients died in hospitals as a result of medical errors. Li et al., (2021) concurred that there are high risks of medical errors because of a lack of interoperability in e-health. Iatrogenic damage emanating from redundant testing of patients is an additional consequence highlighted by Li et al. (2021), but was not identified by this research study's participants. Furthermore, constraints on innovation and the absence of system-wide ICT impacts, are additional effects of non-interoperable e-health systems that were documented by ITU (2017).

Some of the effects of non-interoperable e-health applications gathered from interview respondents corresponded with those discussed in ITU (2017: 10). Burden on the health worker (Participant 1, 2, 3), concurred with ITU (2017) burden on health workers and administrators; patient record cannot be shared (Participants 1, 2, 3, 4, 5, 6, 7 and 8) corresponded with ITU (2017) identification of poor data management (data sharing and consolidation is difficult) and finally wastage of resources (Participants 5, 8 and 10) coincided with the ITU (2017) espousing the wastage of digital health resources.

Summary

This section summarises the effects of lack of interoperability in e-health that were identified by respondents in this study. Some effects were consistent with literature whilst others are not. A few effects in literature were not identified by respondents. The following effects of non-interoperable e-health systems identified by participants were also consistent with literature: burden on the health worker; patient record cannot be shared; wastage of resources and cost. However, the effect, “wastage of drugs” identified by participants could not be located in literature. This could be due to the nature of HIS used in Zimbabwe. On the other hand, the following effects of lack of interoperability in e-health were documented in literature, but were not identified by this study’s participants: medical errors and iatrogenic harm due to redundant testing. These effects might have been recorded in developed countries that have matured in terms of e-health interoperability.

5.2.4 Barriers and enablers of e-health interoperability

Findings and discussions under this section are aligned to objective 3 and 4 respectively. No question(s) on the interview guide directly asked for barriers and enablers of e-health interoperability. However, these (barriers and enablers) were offshoots from the interview data. During the interviews, the researcher paid attention to barriers and enablers that were mentioned in the process. The identified barriers to interoperability were:

- The issue of donor funding and its consequences.
- Challenges of human resources and skills (expressed in terms of insufficient trained software developers and that university education not preparing students effectively for role in e-health
- Limited participation of medical specialists in work on terminology issues in Zimbabwe
- No policy framework guiding work on interoperability.
- Lack of stewardship on issue of interoperability in Zimbabwe.

- Challenges of security
- Challenges of data sharing.
- Siloed development still dominant

The following enablers were identified:

- Presence of OpenHIE as an interoperability platform for developing countries in Asia and Africa.
- Existence of a worldwide technical community supporting OpenHIE.
- Presence of local champions for OpenHIE in some instances, for example in Lesotho.
- Development of reusable software components, no need to reinvent wheel.
- Option of using cloud services to address lack of infrastructure and skills.
- Train the trainer approach to transfer of skills.
- Availability of global ehealth goods. OpenHIE is an example of a global ehealth good.
- Regional conformance testing as a strategy for promoting interoperability.
- Presence of NGOs such as HITRACT that are providing leadership and taking initiative.
- Presence of WHO minimum data standards.

5.3 Analysis using NVivo

This research study was of a qualitative nature, hence NVivo 12 software was used as an analytical tool. The interview transcripts were imported as word files in NVivo 12 and these formed the files which were the primary sources of information i.e. the data set which was analysed in this environment (NVivo12). There were a total of nine files, one file for each interviewee (participant 1-8) and the ninth file (combined participant 9 and 10). Participant 9 and 10 were interviewed simultaneously. Coding in NVivo 12 facilitated the grouping of inter-related or associated concepts (themes) to be arranged or structured into containers known as nodes. These nodes denote themes that emerged from the study. A total of 414 nodes were coded as folders and subfolders thus organising these nodes (themes) into a hierarchical structure in NVivo 12. Four forms of analyses were performed using NVivo 12 namely word cloud, explore diagrams, comparison diagrams and cluster analysis, which are discussed below:

5.3.1 Word cloud

A word cloud shows what the discussion was about. It is also used as evidence that the answers (responses) from interviews were related to what was being investigated. In this research study, word cloud was used to find out the main words that came out under objective 1, 2 and 5. Word cloud was used because it measures the participants' understanding of the topic. Hence the respondents understanding of e-health interoperability was presented using word cloud.

Objective 1 - To determine the current status of e-health implementation in Zimbabwe

Under objective 1, results were analysed in terms of the types of health information systems employed in Zimbabwe as well as the maturity of e-health systems implementation in Zimbabwe.

Types of electronic Health information systems

The word cloud in Figure 4.1 shows the types of electronic health information systems that are used in Zimbabwe. The words “information” and “system” have the highest frequency since responses were centred on types of health information systems used in the country. The types of electronic HIS being used in Zimbabwe include DHIS2, Navision, HRIS, pharmacy systems, EMR, ePOC, logistics information systems, ePMS, laboratory and procurement systems as can be seen from 9. The Health Information Systems depicted in 9 coincided with those HIS identified by participants in section 4.2.

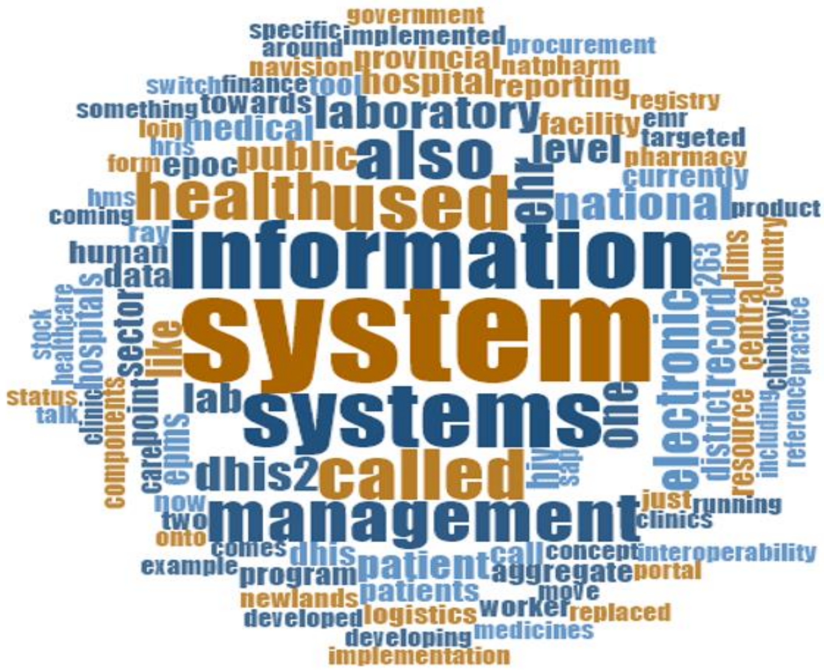

Figure 5.1: Types of electronic Health Information Systems

Maturity level of e-health systems implementation

With regards to the maturity level of e-health systems implementation, the words “systems”, “system”, “information”, “maturity” and “level” were said more frequently. Based on Figure 5.2 below, the maturity level of e-health systems implementation was expressed by phrases such as “data entry” level, “basic” level, level “one”, level “two” and “basic” level. Terms in the word cloud concur with findings from the thematic analysis discussed in section 5.2 that the maturity level of e-health systems implementation is low in Zimbabwe. The names of some e-health systems such as “dhis”, “sap”, “hris” and “pharmacy” also appear in Figure 5.1 since some respondents referred to some of these systems in their responses.

Figure 5.2: Maturity level of e-health systems implementation

Objective 2 -To determine the current status of e-health interoperability in Zimbabwe

The outcome of objective 2 was presented in 3 parts namely: the overall status of e-health interoperability in Zimbabwe, interoperability barriers and interoperability approaches which are presented below.

Overall status of e-health interoperability in Zimbabwe

Based on Figure 5.3 the words frequently mentioned were “interoperate”, “DHIS2”, “ePMS”, “EHR” and “speak”. This is because most respondents referred to the three national e-health systems; DHIS2, ePMS and EHR to describe the status of e-health interoperability. However, the words “infancy”, “disparate”, “isolation”, “immature” and “low” described the status of e-health interoperability in Zimbabwe. These terms can also be used to describe a low level of e-health interoperability which emerged in section 5.2. Accordingly, findings concurred with the thematic analysis in section 5.2 where e-health interoperability status was reported as low.

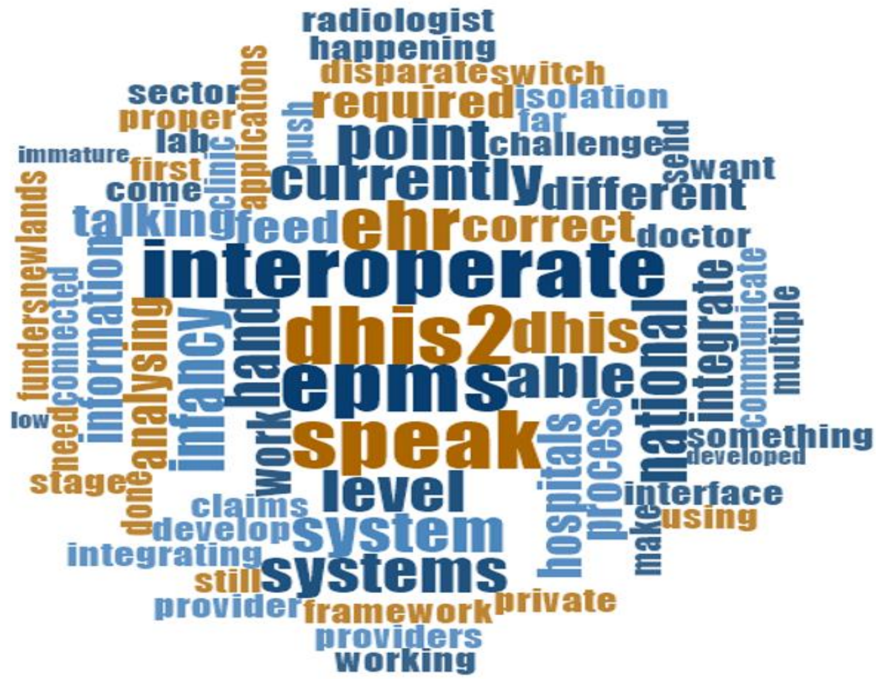

Figure 5.3: Overall status of e-health interoperability

Interoperability barriers

In this research study, the subject of interoperability barriers was guided by the theoretical framework which advocates for technological, organisational, terminology, as well as legal and regulatory factors. These barriers were combined in Figure 5.4 to avoid this section becoming cumbersome. Based on figure 5.4 the barriers to e-health interoperability include governance, data challenges, infrastructure, management, (lack of) interoperability standards, management, connectivity, change (management), funding, leadership, resources, internet, donor funding, cost and skills. These barriers also concur with the barriers discussed in section 5.2 under the thematic analysis.

Figure 5.4: Interoperability barriers

Interoperability approaches

No word in Figure 5.5 below stands for a distinct interoperability approach. However, the words in Figure 5.5 imply a loosely-coupled approach. Words like “openhie”, “information architecture”, “exchange” and “enterprise” point towards a loosely coupled architecture. This tallies with what emerged in the thematic analysis in section 5.2 where respondents suggested a loosely coupled approach for achieving interoperability.

Figure 5.5: Interoperability approaches

Consequences for the lack of e-health interoperability in a developing country context

As shown in Figure 5.6 below, the words “patient”, “records”, “able” and “care” have the highest frequency. This could be because most effects suggested by respondents were centered on patient care and patient records. The effects of a lack of interoperability included those regarding wastage, duplication, cost, and abuse. This could be for example, wastage of resources and/or drugs; duplication of patient records; inability to share patient records. These effects also tallied with those that were presented in section 5.2.

Figure 5.6: Effects of a lack of interoperability

5.3.2 Explore diagrams

Explore diagrams show the relationship between themes and sub-themes in a hierarchy. Explore diagrams enabled this study to identify sub-themes that had to be grouped together so that they could be incorporated in the framework for implementing e-health interoperability. In this study, explore diagrams were created based on sources files and based on nodes.

5.3.2.1 Explore diagrams based on sources (files)

In this case, explore diagrams were created based on files or interview transcripts. Each explore diagram shows the themes and sub-themes associated with each participant. As a result of the number of this study's participants (10), only 2 explore diagrams (for participant 1 and participant 8) are presented (See Figure 5.7) and (Appendix A) respectively. In addition, due to the cumbersome nature of explore diagrams, the several sub-themes associated with each theme are not visible. Only the major themes are visible as end nodes. Accordingly, the themes that emerged from participant 1 (Figure 5.7) includes the loosely coupled approach, absence of legal and policy framework, terminology barriers, e-health strategy and organisational barriers, to name a few. These themes concurred with the findings in section 5.2 (thematic analysis).

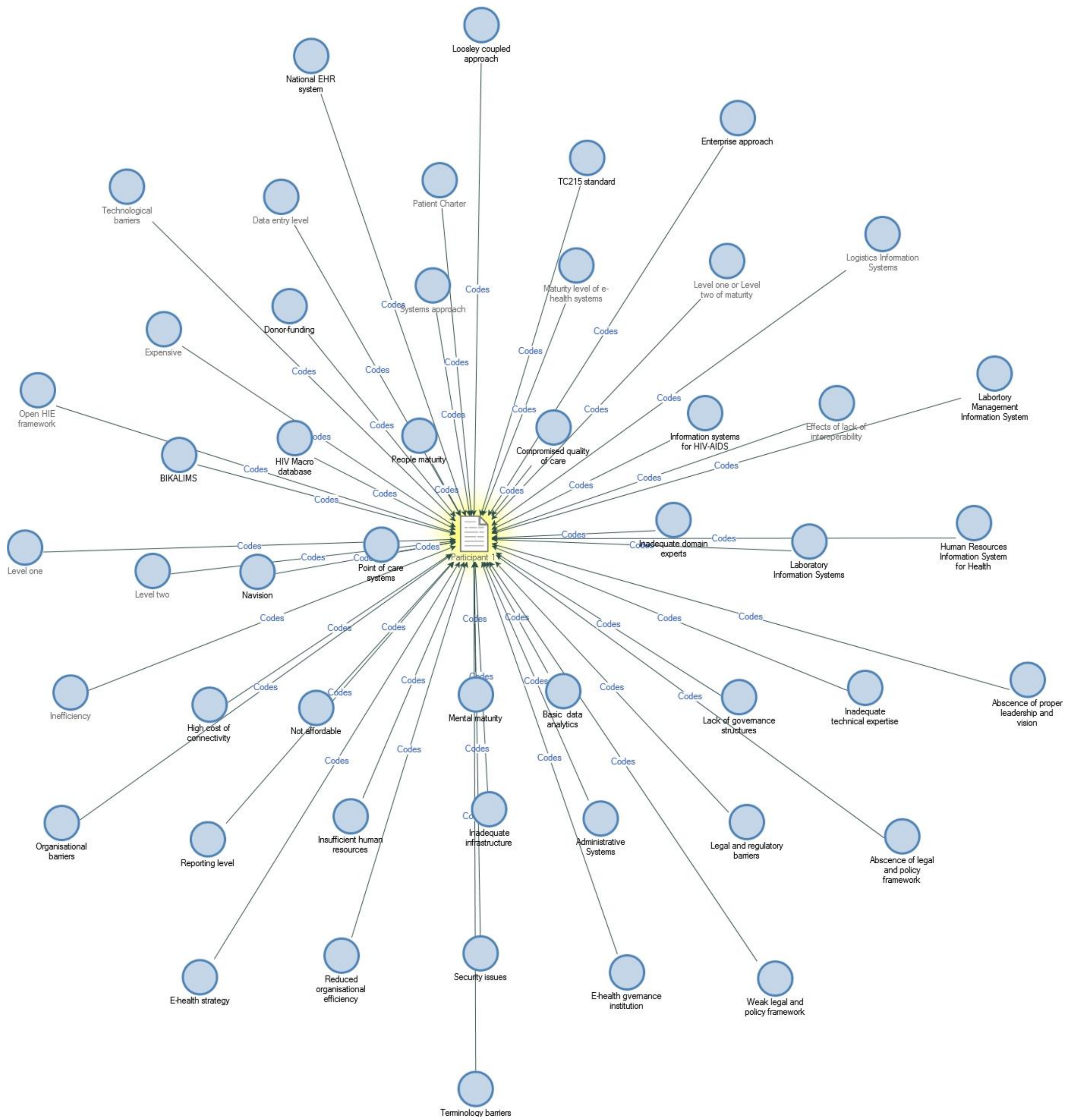

Figure 5.7: Explore diagram for participant 1

The themes that emerged from Participant 8 are shown in Appendix A. The themes include: align law to accommodate e-health, lack of a national e-health budget, e-health interoperability standards, technological barriers, semantic standards lacking, organisational barriers and terminology barriers. These themes corresponded with those discussed in section 4.2.

5.3.2.2 Explore diagrams based on nodes

This type of explore diagrams show the other sources (interview transcripts) in which a particular node (theme) also exists. Using the node (theme), “terminology barriers” from participant 1 (Figure 5.7), it is evident that the same theme also appears in participant 2, 3, 4, 5, 6, 8, 9 and 10 as shown in Figure 4.8 below. It is only participant 7 who did not suggest any terminology barriers. Thus, Figure 4.8 illustrates that the theme “terminology barriers” was common among participants 1, 2, 3, 4, 5, 6, 8, 9 and 10. These findings concur with those in section 4.2. Since the theme “terminology barriers” was common in almost all the participants, it implied that it was a pertinent issue towards the accomplishment of e-health interoperability. As a result, terminology barriers were included in the framework for implementing e-health interoperability.

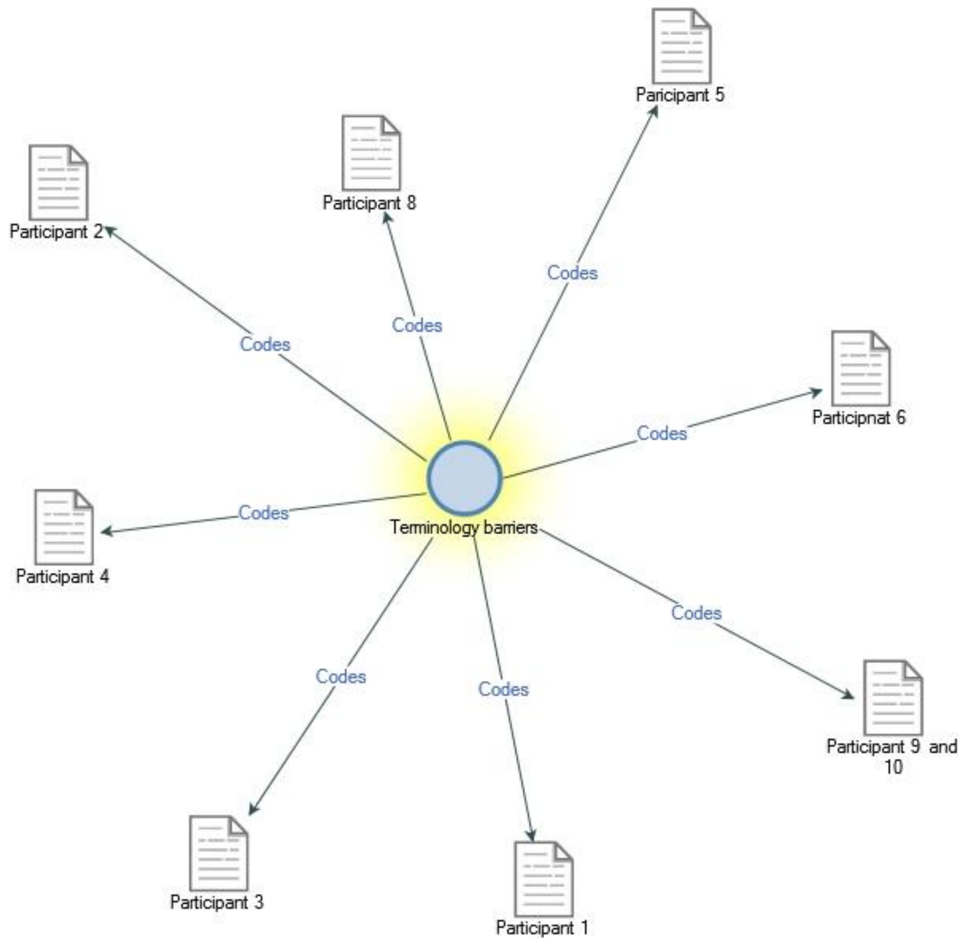

Figure 5.8: Explore diagram based on terminology barriers

An explore diagram generated based on the node (theme) "technological barriers", from participant 8 (Appendix B), reveals that the same theme also appears in all the participants for this study, that is: participant 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. Since the theme technological barriers was common among all the study's participants, it was incorporated in the framework for implementing e-health interoperability.

5.3.3 Comparison diagrams

Comparison diagrams were used to compare files (interview transcripts) so as to show similarities as well as dissimilarities in terms of what respondents contributed (Appendix C). This comparison diagram is for participant 2 and participant 6. The centre of the diagram (Appendix C) shows the issues (themes) that were identified by both participant 2 and participant 6. These issues include e-health strategy, organisational barriers, terminology barriers and technological barriers which were used to develop the proposed framework for implementing e-health interoperability.

The left hand side of the comparison diagram (Appendix C) shows the issues that were raised by participant 2 whilst the right hand side shows the issues that were raised by participant 6. Issues raised by participant 2 (left hand side) include: community of practice; need for governance structures; donor funding; organisational structure changes and inadequate funding.

Issues raised by participant 6 (right hand side) include inadequate resources, lack of standard framework for interoperability and expertise is expensive. Differences in the issues raised could have been as a result of the different areas of specialisation of each participant. Appendix C also reveals that participant 2 generally contributed more issues than participant 6. This might be because participant 2 is a more senior e-health stakeholder compared to participant 6. Despite that issues such as lack of standard framework for interoperability and the need for governance structures were not common for participant 2 and participant 6;

these emerged as dominant issues (themes) among other participants, as a result, they were incorporated in the proposed framework for implementing interoperability in a developing country context.

5.3.4 Cluster analysis

Cluster analysis was performed on the nodes in order to identify themes that were similar or not similar. Cluster analysis (based on word similarity) was suitable for this task, since it is a technique for grouping nodes or sources sharing similar words, or nodes that were coded similarly. Nodes that appear close to each other denote they are similar. In addition, the Jaccard's similarity index was also used to determine how similar or dissimilar nodes were. A Jaccard's coefficient close to 1 implies the two codes are similar while a coefficient further away from 1 entailed the nodes or themes were not similar. Cluster analysis helped in identifying similar themes that the researcher might not have been able to pick up on their own. Similar themes were then grouped together and were then included in developing the framework for implementing e-health interoperability. Accordingly cluster analysis was performed on objective 2: "to determine the current status of e-health interoperability in Zimbabwe" since it addressed issues that would likely be included in developing the framework for implementing e-health interoperability. In this regard, cluster analysis was performed on each of the following themes: organisational barriers, terminology barriers as well as legal and regulatory barriers.

5.3.4.1 Cluster analysis for organisational barriers

In Figure 5.9 the cluster analysis shows that the nodes "need for governance structures" and "lack of governance" are close to each other and are therefore similarly coded. The Jaccard's coefficient of similarity between these two is 0.5 (see Appendix D). Therefore, the two nodes constituted a common theme/phrase related to “governance” that was included in the framework for implementing interoperability in e-health.

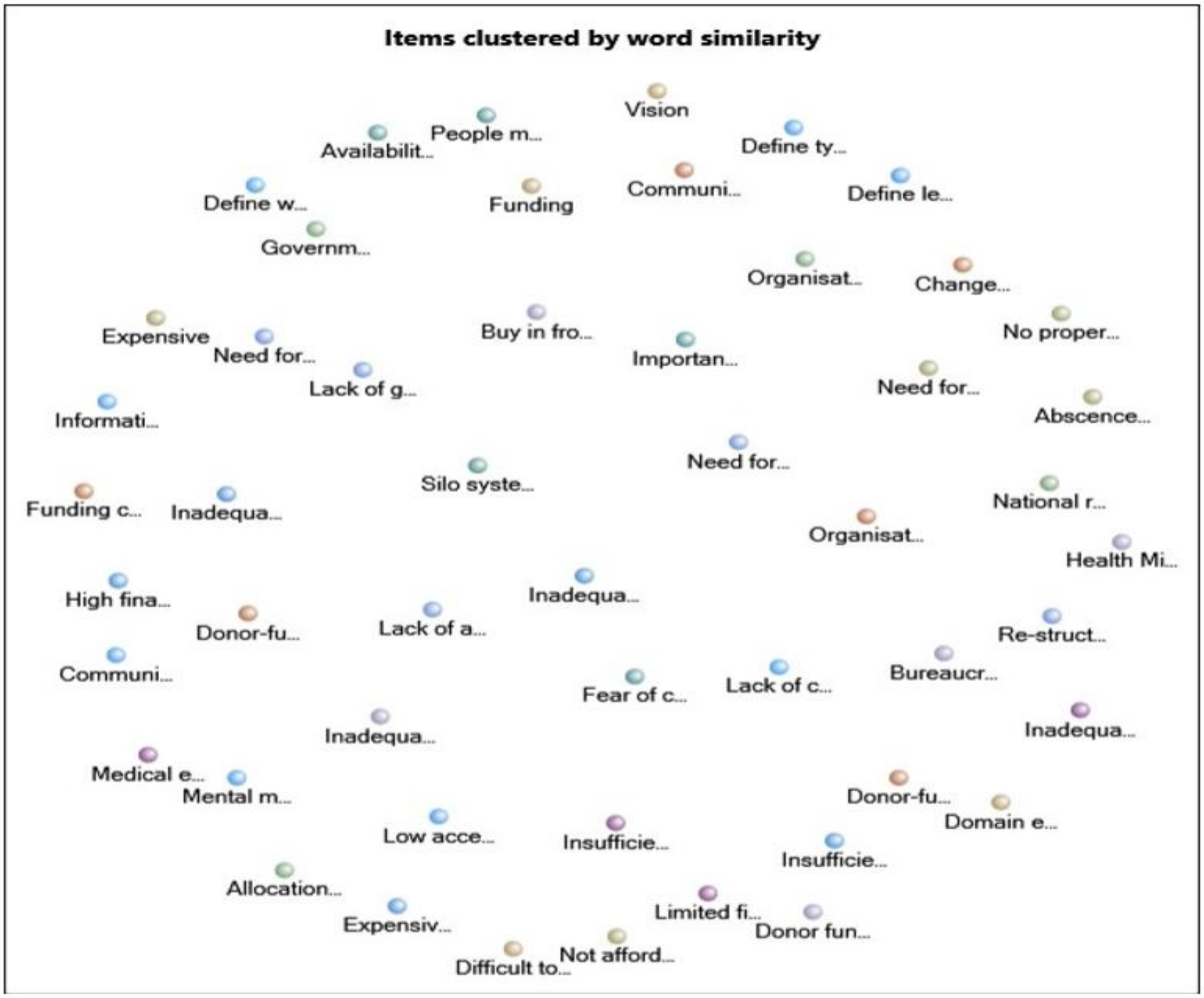

Figure 5.9: Cluster analysis for Organisational barriers

5.3.4.2 Cluster analysis for terminology barriers

As far as terminology barriers are concerned, no nodes were close to each, as shown in Figure 5.10, implying all nodes were dissimilar. In addition, the highest Jaccard’s coefficient for nodes under these theme was 0.3, (see Appendix E), further confirming that the nodes were dissimilar. In this regard a manual method of identifying similar theme was employed.

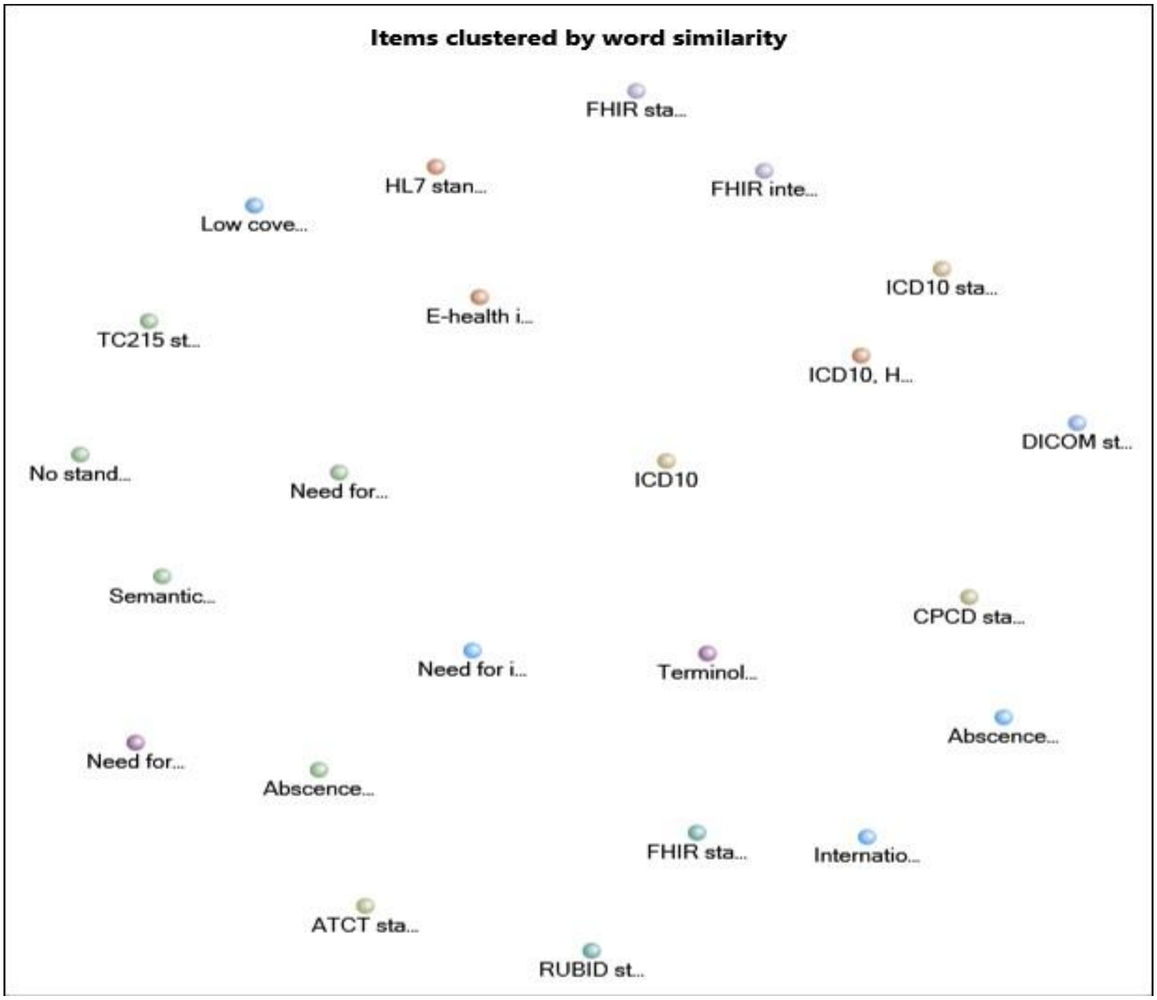

Figure 5.10 Cluster analysis for Terminology barriers

5.3.4.3 Cluster analysis for Legal and regulatory barriers

In terms of legal and regulatory barriers to interoperability, the nodes, “Health Professions Act” and “National Health Act” (top of Figure 5.11) were close to each other on the cluster diagram implying they were similar. In view of that, these two were combined to form a theme related to the need for legislature or law specific to e-health.

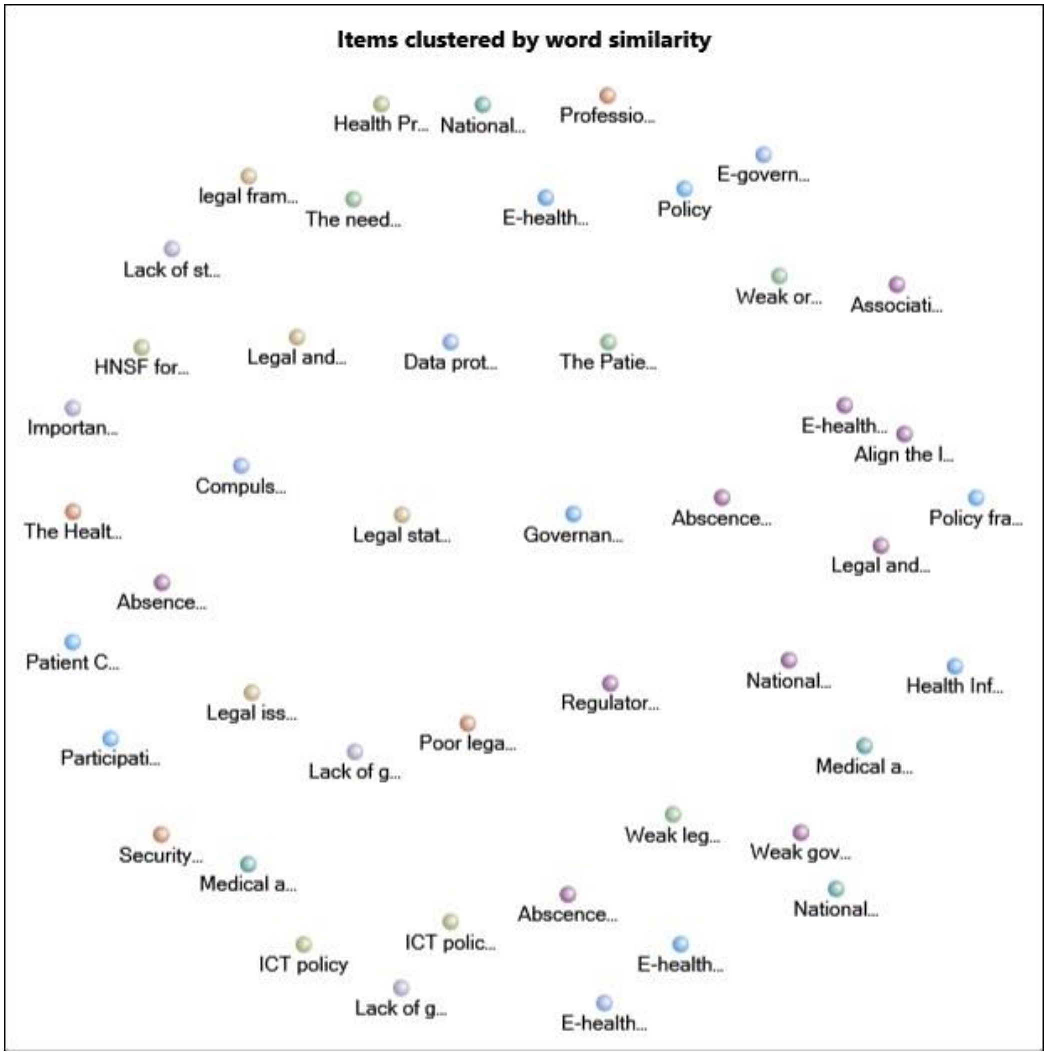

Figure 5.11 Cluster analysis for Legal and regulatory barriers

Still on legal and regulatory barriers, the Jaccard's coefficient of similarity between the nodes, "national e-health strategy" and "absence of an e-health strategy" was 0.5 implying they were similar. In this regard, this meant an e-health strategy became an element that was included in the framework for implementing e-health interoperability (see Appendix F).

This section (section 5.3) presented the research study's NVivo12 findings. Word cloud, explore diagrams, comparison diagrams and cluster analysis were the four forms of analyses conducted using NVivo 12. Analysis in NVivo 12 served a triangulation purpose. The outcome from NVivo 12 largely paralleled the results obtained through thematic analysis in section 5.2.

5.4 Document analysis

The document review conducted by the study was used as a means of triangulation and is supplementary to the data collection done through the interviews. Selected documents were reviewed in line with dominant themes that emanated from interviews with key informants. The four types of documents that were included in the document review were national health planning documents; government acts, bills, policies, and charters; e-health interoperability documents and reports on health information systems.

In table form (Table 5.1), is a list of the documents that were reviewed, arranged by document type.

Table 5.1: List of documents reviewed

	Title of document	Authors / Organisation	Date of release	URL for accessing document
1	**National Health Planning Documents**			
a	Zimbabwe Health Information System Strategy 2009-2014	Ministry of Health and Child Care	2009	https://extranet.who.int/countryplanningcycles/file-repository/ZWE
b	Zimbabwe's E-Health Strategy (Draft) 2012 -2017	Ministry of Health and Child Care	2012	https://www.who.int/goe/policies/countries/zwe/en/
c	National Health Strategy 2016-2020	Ministry of Health and Child Care	2016	https://zdhr.uz.ac.zw/xmlui/handle/123456789/703
d	Zimbabwe Electronic Health Record (EHR) Roadmap 2020-2023	Ministry of Health and Child Care	2020	https://apps.mohcc.gov.zw/mrs-docs/project_documents.html#
2	**Government Acts, Bills, Policies and Charters**			
a	Health Professions Act. Chapter 27:19	Government of Zimbabwe	2000	http://www.hpa.co.zw/downloads.php
b	Client Service Charter	Ministry of Health and Child Care	2012	https://zdhr.uz.ac.zw/handle/123456789/1418
c	Patient`s Charter Zimbabwe	Ministry of Health and Child Care	1996	https://zdhr.uz.ac.zw/xmlui/handle/123456789/1685
d	Cyber Security and Data Protection Bill	Government of Zimbabwe	2019	http://www.veritaszim.net/node/4167

e	Zimbabwe National Policy for Information and Communications Technology (ICT)	Government of Zimbabwe – Ministry of ICT	2016	http://www.veritaszim.net/node/1818
3	**E-health Interoperability documents**			
	Digital Health Platform: Building a Digital Information Infrastructure (Infostructure) for Health. Handbook.	ITU	2017	Provided by interview participant.
4	**Reports on Health Information Systems**			
a	Electronic Patient Management System-ePMS Zimbabwe	United Nations Development Program (UNDP)	2014	https://www.zw.undp.org/content/dam/zimbabwe/docs/hivaids/UNDP_ZW_HIVAIDS_epms_zimbabwe.pdf
b	Innovation in the Zimbabwe Health Information	UNDP	2014	https://www.undp-capacitydevelopment-health.org/files/DHIS-Zimbabwe-28.03.15.pdf

The reviewed documents were grouped by purpose or function. First, were national health planning documents authored by the Ministry of Health and Child Care for the purposes of providing guidance in the provision of health services. Examples were the National Health Strategy (2016-2020) and the Zimbabwe Electronic Health Record (EHR) Roadmap 2020-2023. These were also characterised by time frames, after which another version of the document would be compiled for the current period. However, some documents were not current such as the Zimbabwe Health Information System Strategy (2009-2014) and some were still in draft form such as the E-health Strategy for Zimbabwe-Draft (2012-2017). This was because the recent documents had not been yet approved or the final document (in the case of draft) had not yet been finalised. Second were Government Acts, Bills, Policies and Charters that constituted the legal component of health. Examples were the Health Professions Act Chapter 27:19 and the Patients Charter. Third were e-health interoperability documents and finally reports on health information systems (HISs). The last two categories of documents were authored by international organisations.

The documents were acquired from various sources. Some documents were availed by respondents via email after the interviews. Documents were also authored by the Health Ministry, and downloaded from the Ministry's website. Other documents referred to by some respondents during interviews were also downloaded from the Internet.

Thematic analysis was the method used for the document review. Fereday and Muir-Cochrane (2006) cited in Bowen (2009:32) defined thematic analysis as "… a form of pattern recognition within the data, with emerging themes becoming the categories for analysis". The emerging themes that emanated from analysing interview responses were used to inform the document review. The themes identified from the reviewed documents were centred on e-health implementation and the status of e-health interoperability, based on objectives 1 and 2 namely to determine the current status of e-health implementation in Zimbabwe and to determine the current status of e-health inter-operability in Zimbabwe. In this regard, the thematic analysis conformed to themes related to objectives one and two for this research study.

5.4.1 Current status of e-health implementation in Zimbabwe

The major themes of the document review were the types of health information systems as well as maturity levels of e-health systems implementation.

5.4.1.1 Types of Health Information Systems

It was expected that the Zimbabwe Health Information Systems Strategy (ZHISS) (2009-2014) was one national document that would give details of HISs running in the country, nevertheless it did not contain such information. Examples of information contained in the ZHISS is a HIS logical framework that included strategies such as "developing an e-health framework and guidelines" (Ministry of Health and Child Care, 2009:14) and "establishment of a central health information repository" (Ministry of Health and Child Care 2009:14). This could have been because electronic health information systems were not yet common at the time this Health Information Systems strategy document was issued in 2009. As a result, the researcher then resorted to documents authored by international organisations. Almost all of the Health Information Systems (HIS) currently running in Zimbabwe were the same as those propounded by ITU (2017). From the list of types of health information systems proposed by ITU (2017:32), Zimbabwe had the following HISs running: EHR and health Information resources (such as the national EHR / Impilo), Health Management Information System (such as DHIS-2), Human Resource Information System (such as HRIS), Laboratory and Diagnostic system (such as Laboratory Information Management System), Logistics Management Information Systems (such as Navision) and Pharmacy systems. Therefore, the HISs implemented in Zimbabwe were aligned to those acknowledged by some e-health related international organisations. Out of the twenty-four types of HIS proposed by ITU (2017), only six were implemented in Zimbabwe. The implementation rate of 25% (6 out of 24) was an indication that e-health maturity in Zimbabwe was low. This concurred with the analysis of themes of the interviews that disclosed that current status of e-health implementation in Zimbabwe was low.

5.4.1.2 Maturity level of e-health systems implementation

The document review concurred with interview findings that the maturity level for e-health systems implementation was low and characterised by vertical siloed systems that could not exchange health data. The Ministry of Health and Child Care (2020:12) Zimbabwe Electronic Health Record system (EHR) Roadmap 2020-2023 supported these findings stating:

> *"Many were disease-focused systems and collected data whose main function was to fulfil program management requirements".*

There was only one national electronic HIS namely DHIS2 for reporting aggregate data. DHIS2 was running in all District and Provincial hospitals. The EHR system, Impilo, which is envisioned to be the country's flagship for interoperability in electronic health was still work in progress, and very few facilities were using the system (Harare municipality clinics and health facilities in the Uzumba-Maramba-Pfungwe district). LIMS and ePMS were also running in selected facilities. Although HIV/AIDS was at the top of Zimbabwe's health burden, with 15% of the adult population being HIV positive (Ministry of Health and Child Care, 2016) and with 75% of them on Antiretroviral Therapy (ART) (WHO, 2017), only selected health facilities were running an electronic system (ePMS) for monitoring HIV/AIDS patients on ART.

While interview respondents rated the maturity levels of e-health systems implementation as low, the document review suggested a better maturity level. For instance, the country had a national system, DHIS2, for reporting and aggregating health data that was running in all district and provincial health centres. In addition, there was good progress reported for the national EHR system, Impilo that was introduced in 2016. The Ministry of Health and Child Care (2020:6) reported that:

> *"As of March 2020, we are pleased to announce the retirement of eight redundant data collection systems in facilities running Impilo, reducing burden for health workers and centralising patient data in one place accessible to all MoHCC programmes".*

In addition, the following modules had already been developed for the comprehensive EHR system: the HIV Testing Service (HTS), Option B+, TB screening, Pharmacy, Outpatient Department (OPD), Laboratory, Maternity, Ante-natal Care (ANC), Post-Natal Care (PNC), Expanded Programme on Immunisation (EPI), Nutrition and Growth Monitoring (Ministry of Health and Child Care, 2020). The plan is to customise and develop additional modules as the system would be scaled up. As of the year 2020, 116 health facilities deployed the EHR (Impilo) system and plans were underway to implement the EHR system, nationwide by 2023. In the long-term the EHR system should become "a standards-based, interoperable, patient-centric electronic health records system in all the health facilities in Zimbabwe" (Ministry of Health and

Child Care (2020:16). All these achievements suggest a maturity level of e-health systems implementation that cannot be described as "low".

5.4.2 Current status of e-health interoperability in Zimbabwe.

The current status of e-health interoperability is presented with regards to interoperability barriers (technological, organizational, terminology as well as legal and regulatory barriers) and interoperability approaches.

5.4.2.1 Interoperability barriers

Interoperability barriers consist of technological, organizational, terminology as well as legal and regulatory barriers, which are discussed in the following paragraphs.

Technological barriers

The technological barriers that were highlighted by interviewees were synonymous with those revealed by the document review. This included internet connectivity, availability of computers, internet and electricity supply, amongst others. Zimbabwe's E-Health Strategy Draft of 2012-2017 concurred that computing infrastructure such as PCs and network connectivity hampered e-health efforts in the country. The e-health strategy draft further proposes how the infrastructure challenges can be addressed. For instance, the E-Health Strategy Draft (2012-2017) suggests that with regards to network security, a clinical care system should be highly secured with encryption together with authentication and authorisation. With respect to network ubiquity, service points for clinical systems must be accessible only at point of care, unlike patient knowledge repositories that must be more widely available for enhanced use.

Organisational barriers

Organisational barriers such as change management, donor-funding, human resources and financial resources that were highlighted by interviewees were the same as those gathered through document review. Interview findings and documents reviewed concurred that change management was critical whenever a HIS was implemented. Although the EHR system, Impilo, was yet to be implemented nationwide, it already factored issues of change management on the part of users of the system. For instance, with the deployment of Impilo:

> *"Some current tasks of Health Information Officers (HIOs) and Data Entry Clerks (DECs) will no longer be needed following Impilo deployment (e.g., data capture in standalone EPMS system, tally counting, and report preparation)".* (Ministry of Health and Child Care, 2020:43)

To address this change, there were plans to convert some of these personnel into proper ICT support roles that would provide support for the national EHR system and others that the Health Ministry would implement. Nevertheless, resistance could be anticipated where re-training and/ or up-skilling would be required. Although the ZHISS (2009-2014) reported that all district offices and provincial Medical Directorates had computers, they were poorly utilised for processing, communicating and distribution of health data.

With respect to donor funding, the implementation of national HISs such as DHIS2 and ePMS was donor-funded by partners such as UNDP. In addition, the national EHR project had the following partners: The U.S. President's Emergency Plan for AIDS Relief (PEPFAR), Research

Triangle Institute (RTI), United Nations Population Fund (UNFPA), Catholic Organization for Relief and Development Aid (CORDAID) and the Global Fund.

Reviewed documents also highlighted that insufficient funds were an impediment to health service delivery, let alone digital health. According to the Ministry of Health's (2016: 68) National Health Strategy 2016-2020,

> *"The country has failed to meet the Abuja Declaration commitments (spending 15% total government expenditure on health) from the time it was signed up".*

However, "The health budget allocation increased from an average of 7% in the past five years to 10% in 2020" (UNICEF, 2020:5). Still, there was need for a stand-alone budget for e-health since the initiative is resource-intensive.

In terms of human resources for digital health, both interview respondents and the document review results concurred that, it was inadequate. For instance, as of 2011 there was a vacancy rate of 27% for specialists in surveillance and Health Information Systems (JICA, 2012). Overall, interview findings coincided with findings from the document review. However, the report did not suggest ways of solving this human resources challenge.

Terminology barriers

With respect to terminology barriers, interview findings and document review were in agreement. These revolved around standards such as, international standards, interoperability standards, coding, and diagnosis standards. The issue of standards was discussed in the context of the national EHR system. This could be because the national EHR was a home-grown solution by Zimbabweans, thus, familiarity with standards. The Interview and document review data concurred that international standards were used. However, the document review showed that standards implemented to date in the EHR were mostly content standards namely, classification standards such as ICD10 for classification of diseases and conditions. Almost all study participants identified ICD10 as one standard that was implemented in the EHR. The document review revealed that the following content standards were already implemented in the EHR: CPT for classification of procedures, ATC for classification of medications and ICPC-2 for classification of patient complaints and health worker observations, notably none of the later were identified during interviews (except for ICD-10). Also, LOINC for classification of Lab tests was yet to be implemented in the EHR. In terms of data transfer/sharing standards, HL7 for sharing data between systems, was identified by both interviews and the document review. The standard, Digital Imaging and Communications in Medicine (DICOMM), used for distributing image data was mentioned in the documents that were reviewed, however none of the interview participants mentioned it. In addition, both HL7 and DICOMM were yet to be implemented in the EHR (Zimbabwe EHR Roadmap 2020-2023).

Section 3.1 entitled “Data quality and Standards”, in the The Zimbabwe Health Information System Strategy (2009-2014) indirectly referred to the need for interoperability in health. The section underlined that standards were pertinent to facilitate the sharing of health data as well as maintain security and privacy of exchanged data. The Zimbabwe Health Information System Strategy (2009-2014) further stated that the e-health framework will guide the development of standards associated with using ICTs in healthcare. According to Zimbabwe's e-health strategy draft (2012-2017), standards are crucial for enabling the effective sharing of information among all care givers and customers of healthcare services and hence an e-health framework would guide the advancement of ICT-realted standards for health. This need for standards to enable the sharing of health data concurs with the theme of terminology barriers which is a part of interoperability barriers. Thus, the document review further supported the themes that emerged from interviews.

Legal and regulatory barriers

Findings from the document review concurred with findings from interviews that there was no legal or regulatory framework for e-health implementation and e-health interoperability in Zimbabwe, and that gaps existed in the current health related laws. The issue of gaps in legislation was also revealed by the National ICT policy. Policy statements under the e-commerce development and implementation section of the ICT policy, read:

> *"Enable the development of legislation, regulations and policies and programs for the following: e-Health, e-Agriculture, e-Manufacturing, e-Transport, e-Tourism and e-Mining".* (Zimbabwe ICT Policy, 2015: 29).

This showed that the government was aware of the need for laws, policies and regulations for e-health. However, no policy statement was specifically stated for e-health. This could explain why study participants bemoaned the absence of precise ICT-related regulations and policies to do with e-health.

The Zimbabwe Health Information System Strategy (2009-2014) also touched on issues of e-health. Under the Health Information System (HIS) Logical Framework (Ministry of Health and Child Welfare, n.d:11), one of the specific objectives stated is “To harmonise the functions of the Health Information and Surveillance Systems”. In order for this objective to be achieved, one of the strategies was “Develop e-health framework and guidelines”. One of the activities for this strategy is to “Form a Technical Working Group (TWG) to develop e-health framework to guide MOHCW and partners in the use of ICT in the health sector based on national ICT policy and guidelines” (Ministry of Health and Child Welfare, n.d. p.11). From this document analysis it was evident that the government was moving in the right direction for e-health and subsequently e-health interoperability. However, it could not be established whether the e-health framework was developed since it could not be obtained from neither the interviewees nor from online resources. It is also important to note that the MoHCC was cognisant of the fact that the e-health framework should be informed by the National ICT policy and guidelines.

The establishment of the National E-health Strategy (2012-2017) Draft could have been an attempt to address this issue of the need for a framework for e-health and guidelines. However, the E-health strategy (2012-2017) was still a draft. One senior Ministry of Health official who participated in this research study revealed that the actual e-health strategy was awaiting approval.

In this case, the plan to have an e-health framework and guidelines was procedural and standard, but implementing this part of the Zimbabwe Health Information System Strategy is clearly a challenge, since the country does not have such a framework to date. This was confirmed by a majority of the interview respondents who lamented that the country had no specific government instrument (such as a national framework) to guide e-health interoperability. Thus, the documents reviewed mirrored the interview findings in line with the absence of a regulatory e-health and e-health interoperability framework in the country, unlike in some developing countries like South Africa. South Africa's Department of Health's National Health Normative Standards Framework for Interoperability is now law in the South African nation. In this regard, having a policy or framework would also compel stakeholders and system developers to implement interoperability and not ignore it.

The Health Professions Act Chapter 27:19 of 2000 and the Client Service Charter of 2012, are the laws that govern the health profession in Zimbabwe. The Zimbabwe Health Information System Strategy (2009-2014) and some of the interview participants (especially Participant 3) concurred that these were the legal instruments that regulated health-related matters in the country. Nevertheless, both the Health Professions Act (2020) and the Client Service Charter (2012) were silent about e-health. None of these documents explicitly mentioned e-health, and even still e-health interoperability. The Health Professions Act however explicitly prohibited health practitioners from advertising their services or skills in both print media and electronic media. The electronic media stipulated here includes websites and electronic billboards. This, in a way contradicted with the need for ICTs in health, and is contradictory to what the national ICT policy and ZHISS (2009-2014) were trying to promote. This was is in agreement with interview findings.

Concerning the confidentiality of patient records, the Ministry of health's Patient`s Charter (1996:2) paralleled interview findings that "… all communication and other records relating to patient's care (to) be treated as confidential unless release is authorized in writing by the patient". It appeared the Patient's Charter did not cater for electronic patient records in this regard, where the method of consent could be different. In addition, considering the use of shared health record via repositories, the written consent requirement would likely fall short. Generally, issues raised by interviewees agreed with what was documented in the Cyber security and data protection bill of 2019, the Health Professions Act of 2000, and the Patient`s Charter of 1996. Moreover, none of the legal statutes mandated private practitioners to report to the MoHCC. This perpetuated fragmentation of patient data.

5.4.2.2 Interoperability approaches

There was a consensus of findings between interviews and document review, in that a loosely-coupled approach was ideal to facilitate e-health interoperability. For instance, both the Zimbabwe E-Health Strategy Draft of 2012-2017 and the Impilo national EHR proposed an enterprise architecture for health information exchange thus suggesting a loosely-coupled approach for interoperability in e-health. An enterprise architecture approach enables fragmented HISs to share data effectively. Although not explicitly stated, the ZHISS could have alluded to a loosely-coupled approach for interoperability when it stated that HIS software should be flexible.

5.4.3 Effects of a lack of interoperability

Since national documents on effects of lack of interoperability could not be obtained, documents provided by officials from Jembi Health Systems, who were part of the interview respondents, were used. In this case reviewed documents concurred with interview findings. The effects of non-interoperable systems discussed by ITU (2017) paralleled with the effects highlighted from interviews. These were poor data management (Participants 1, 2, 3, 4, 5, 6, 7 and 8); burden on health workers and administrators (Participant 1, 2, 3); wastage of (digital health) resources (Participants 5, 8 and 10) and constraints to innovation (Participant 8).

In terms of poor data management, the Ministry of Health and Child Care (2020:14) agreed with interview findings that:

> *"In many cases, data elements are being captured more than once into various tools that target specific data and information needs for individual programs and departments. This has resulted in some data discrepancies, whereby values for the same data element differ from source to source".*

The concern of burdening health workers was also elaborated by the Ministry of Health and Child Care (2020:13) that:

> *"… the nursing staff, who are the primary data collectors at the health-facility level, are overwhelmed by a plethora of registers, tally sheets, and monthly and quarterly reporting forms that they manage in conjunction with attending to*

patients. The resultant effect of these numerous registers and forms has made it difficult for nurses to give quality care to patients because more and more time is now being spent on making entries into registers and forms".

The burden on the health worker due to non-interoperable systems was also reiterated by the Global Fund's Office of the Inspector General (GFOIG), (2013) cited in the Ministry of Health and Child Care (2020:13) that

> "*heavy staff work load (One example from our visits to two facilities showed that two nurses were expected to complete 19 registers in addition to the provision of health services)."*

The ripple consequence of this overwhelming need for capturing and recording data was an obstacle to the health workers' core duties of patient care and management.

It should be noted that very few documents were available to the researcher, hence some documents were cited often. The study also revealed that many of the issues that were highlighted by interviewees were not evident in extant research. This could be an indication that the e-health domain is an area that is under-researched.

5.5 Interoperability framework for developing country contexts

Various e-health information systems have been implemented in Zimbabwe, but almost all of them do not talk to each other, including those that fulfill the same objective. For instance, the electronic Point of Care (ePOC) system and the electronic Patient Management System (ePMS), even though they are both used to monitor HIV patients, they do not speak to each other. Fanta and Pretorius (2018) concur that e-health systems in developing countries are fragmented due to pressure from donors, political factors and economic factors. Fanta and Pretorius (2018) maintain that most electronic health information systems are donor-funded and are typically modelled around specific diseases such as malaria, TB or HIV/AIDS based on the information requirements of the donor(s). This results in several information systems running in the same healthcare amenity but devoid of exchanging information (non-interoperable systems). It can be said that the healthcare system in Zimbabwe is characterised by a random implementation of non-interoperable HIS resulting in silo systems.

It is anticipated that the proposed framework for implementing e-health interoperability in developing countries will act as a valuable tool for guiding stakeholders in developing countries when implementing interoperable HIS. This is consistent with Luna et al. (2019) that the purpose of a framework is to recommend interoperability guidelines for the exchange of information. It is not the goal of this framework to prescribe pre-defined solutions in terms of software to use. Rather, the intention of the proposed framework is to answer the question, “If a country wants to implement e-health interoperability, how do they go about it?” Frameworks for interoperability have been implemented in both developing and developed countries and are yielding positive results (Luna et al., 2019). However, the researcher acknowledges that acceptance of this framework by the community of e-health practitioners can happen over time, after it is widely known.

The proposed framework is presented in two formats namely: the Activity framework, Figure 4.12 and the Architectural components framework, Figure 4.13. The Activity framework, Figure 4.12 is a detailed action-driven framework that illustrates a step-by-step approach to implementing interoperable health information systems. First, the following question needs to be asked, “What is the current status of e-health interoperability?” In this context, it means the following needs to be identified: whether there are siloed systems or whether there are integrated systems in the in the current e-health ecosystem of the country. This classification is important because the answer to this question informs the next activity. If there are siloed systems, then there is a need to find out if the systems are built on an architecture that facilitates the exchange of information, such as a Health Information Exchange (HIE). Determining the architecture for interoperability is important because it is possible to have siloed systems that are built based on a well-recognised architecture for interoperability, that is not however interconnected, probably because these siloed systems’ existence is unknown and also that the architecture they are built on may not be known. Therefore, knowing the details of the architecture on which these siloed systems are built assists in determining the architecture to adopt for interoperability.

Next, it must be determined if there are integrated systems in the current e-health ecosystem of the country. If yes, then there is a need to find out if these integrated systems are built on an architecture that facilitates information exchange. If the health information exchange architecture used for integrated systems is the same as the one for siloed systems, then there is no need to reinvent the wheel. Instead that common architecture is applied to both systems (siloed and integrated) and then it is implemented in a national e-health strategy that prescribes the adoption of a standards-based unified (loosely-coupled) approach for interoperability.

On the other hand, if there are no integrated systems then the questions that must be asked is, if there is an e-health strategy that is used in designing these systems. The same applies if there are no siloed systems. Again it must be asked, if there is an e-health strategy. If an e-health strategy exists, then the e-health strategy must be checked to ascertain if it prescribes an interoperability architecture. If an e-health strategy exists, then there can be go ahead to test for compliance through connectathons and hackathons. Under testing for compliance, performing the regional conformance test is critical since it ensures cross border interoperability. The compliance tests would also determine the kind of training courses that should be offered in order to facilitate the building of architecture-based systems.

Activity framework

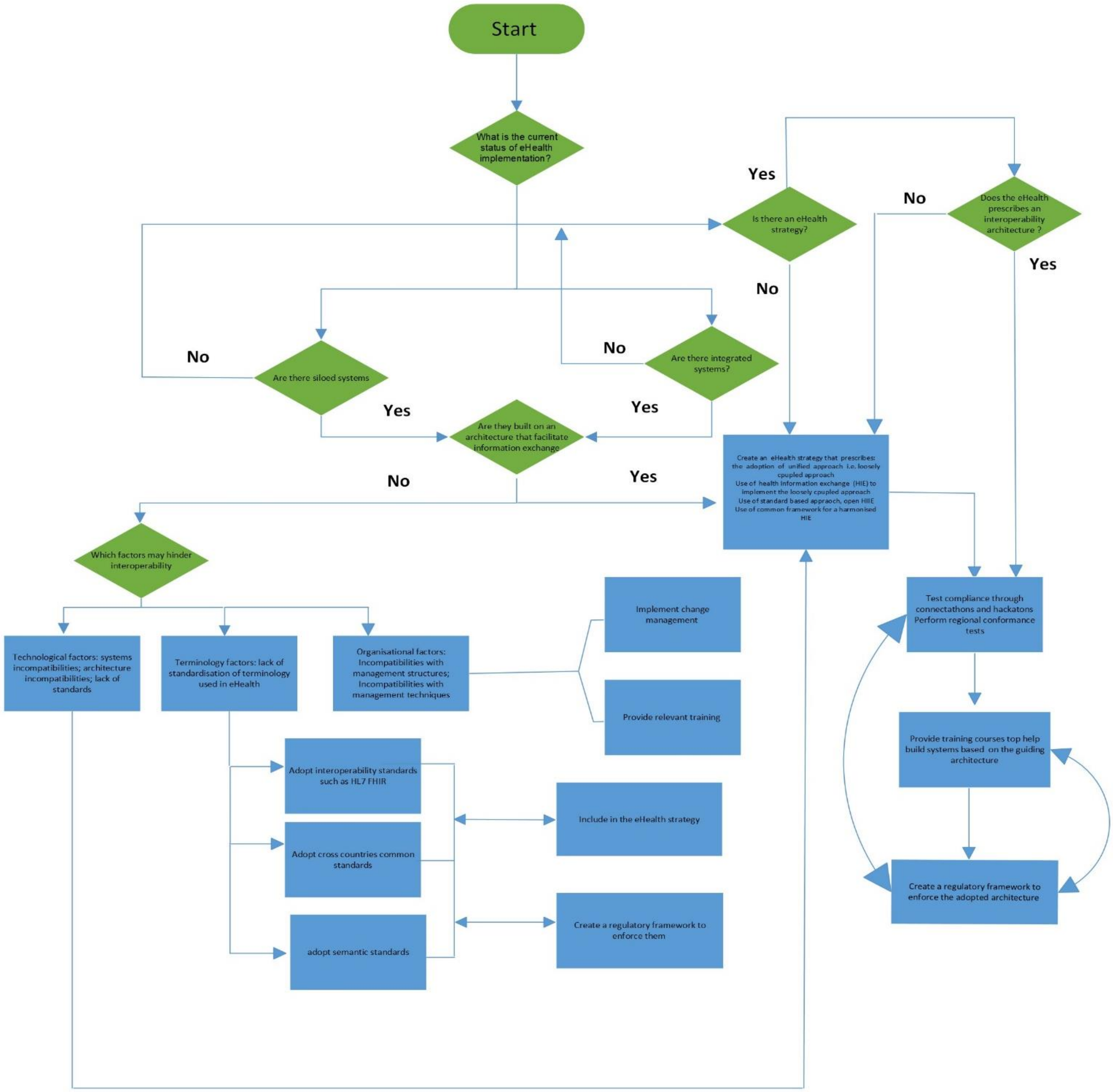

Figure 5.12: Activity framework for implementing e-health interoperability in a developing country context

In this context, training for e-health interoperability should not only be limited to offerings by experts like Jembi Health systems, it should also include issues of curriculum in computer science and IT-related programs in universities so that they include components of e-health interoperability. Finally, a regulatory framework for e-health interoperability is developed. A regulatory framework is created after a certain period, such as three or five years of seeing what works and what is best for a given country. The developed regulatory framework will be updated over time based on the changes in its environment that are associated with conformance testing and training. The regulatory framework may also lead to changes in conformance testing as indicated by that arrow connecting "regulatory framework" and "test compliance through connectathons". The three elements, conformance testing, training and regulatory framework constitute the maturity model for e-health interoperability, as suggested by interviewees. Such a maturity model is expected to mature and be properly enforced.

On the other hand (the top left side of Figure 4.12), if there are information systems which cannot be classified as silo systems nor integrated systems, then the next step is to check whether their development was guided by an e-health strategy. If not, then create an e-health strategy that prescribes a standards-based approach while adopting a health information exchange. If it turns out that these systems were developed based on an e-health strategy, then the e-health strategy must be checked to determine if it prescribes an architecture for interoperability. If the answer is no, then creating an e-health strategy would be the next step. Conversely, if the e-health strategy prescribes an interoperability architecture, then testing for compliance can proceed, followed by providing the relevant training and finally creating a regulatory framework. Furthermore, if the information systems development process was based on an e-health strategy that prescribes a standards-based approach, then the next step is to test these systems for conformance through hackathons and connectathons.

However, if the available siloed systems and integrated systems are not built on any architecture for interoperability, then, the barriers (factors) that will be hindrances to these systems' interoperability are identified. These are technological barriers, terminology barriers and organisational barriers. Technological barriers consist of systems incompatibilities, architecture incompatibilities and lack of standards. Terminology barriers essentially refer to lack of standardisation of terminology used in e-health implementation. Organisational factors consist of incompatibilities with management structures as well as incompatibilities with management techniques. The proposed framework further suggests methods addressing the three types of barriers presented. The technological barriers will be mainly solved by having an e-health strategy that prescribes the technological standards, the architecture and the systems that should be adopted. For terminology barriers the prescribed solutions are adopting interoperability standards such as HL7FHIR, adopting cross country common standards and adopting semantic standards. These solutions will have to be incorporated in an e-health strategy and enforced through a regulatory framework. For organisational barriers, the solution would be implementing change management as well as providing relevant training.

Based on this framework, it is clear that the e-health strategy is a very important component in addressing most of the challenges related to implementing interoperability in e-health. Information systems that were developed based on an e-health strategy must be tested for compliance through connectathons and hackathons. Regional conformance tests are more preferable in the African context because resources can be pooled together and have interoperability introduced in several countries, since developing countries are constrained on resources. Implementing interoperability thoroughly using the country-by-country approach is likely to be more expensive for developing countries due to resource constraints. This regional approach would be different to those approaches adopted by countries in North America that have more resources and can therefore afford to comprehensively implement interoperability as individual countries. After testing for compliance to the e-health strategy, then follows training on building standards-based interoperable systems. The training offered is based on the results of the conformance tests.

After training, then follows creating a regulatory framework to enforce the adopted architecture. It is critical that before enforcement through a regulatory framework, there is need to monitor conformance to the e-health strategy and then offer appropriate training based on the outcome of the conformance tests. It is essential for organisations to bear in mind that the regulatory framework will be adjusted occasionally based on findings of the conformance tests. An example is the introduction of new interoperability laws in one's country that may not be compatible with regional interoperability standards. Thus, that country would have to update its regulatory framework to reflect those changes. On the other hand, the regulatory framework should be informed by the results of the training. This is because individuals, organisations and countries are likely to adopt the training process in different ways. An assessment would be carried out to determine whether the training is effective. This would also inform the kind of training enforced, including the mode and intervals of training.

Architectural components framework

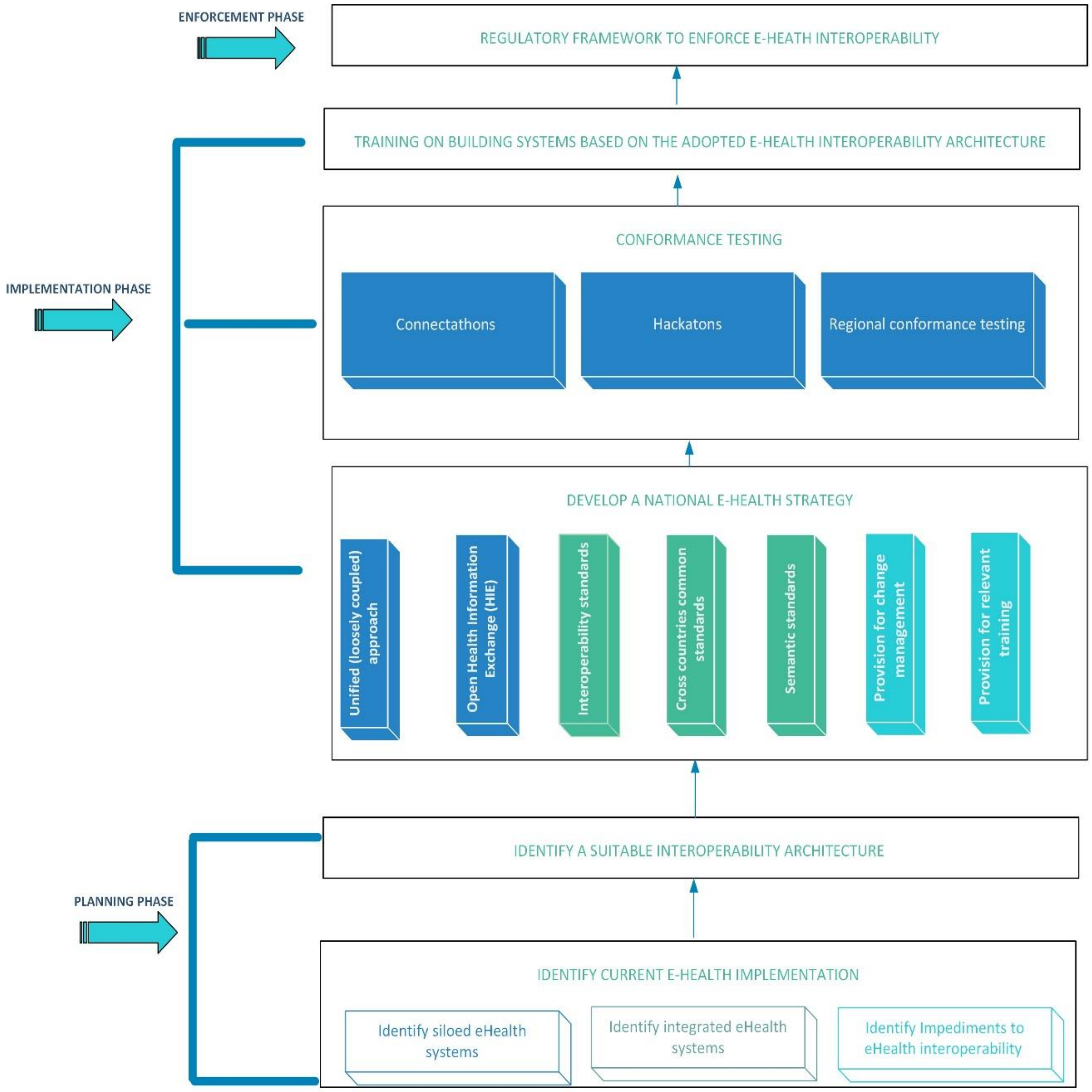

Figure 5.13: Architectural components framework for implementing e-health interoperability in a developing country context.

The Architectural components framework, Figure 5.13, is a high-level framework that illustrates the relationships between the various components and is summarised as opposed to the detailed Activity framework in Figure5.12, presented earlier. The Architectural components framework, Figure 4.13 is comprised of 3 phases namely: the planning phase, the implementation phase, and the enforcement phase.

The planning phase involves two components namely, identifying the current e-health implementation and identifying a suitable interoperability architecture. Under identifying the current e-health implementation there are sub-items: identifying siloed e-health systems, identifying integrated e-health systems as well as identifying impediments to e-health interoperability. Based on the current e-health implementation, a suitable interoperability architecture is developed. Next is developing a national e-heath strategy.

Developing an e-health strategy, testing for conformance to the e-health strategy and training on building systems based on the adopted e-health interoperability architecture all constitute the implementation phase. The national e-health strategy should provide guidance on adopting a unified (or loosely coupled) approach. It should also prescribe use of an open Health Information Exchange (HIE). The e-health strategy should also prescribe interoperability standards so that there will not be incompatibilities that would lead to non-interoperable systems. Cross country standards should also be articulated to facilitate cross-border e-health interoperability. The prescribed semantic standards have to be of a regional or international nature. The national e-health strategy should also have provision for change management and provision for relevant training.

After developing a national e-health strategy, information systems developed based on this e-health strategy should undergo conformance testing, thus the conformance testing block. Depending on the results conformance assessments, developers of the information systems should under-go relevant training on how to build systems based on the adopted e-health interoperability architecture. Thus the three elements constituting the implementation phase are: developing a national e-health strategy, conformance testing and training.

After the implementation phase comes the enforcement phase. Creating a regulatory framework is what essentially addressed in this phase. A regulatory framework is enforced after several years of running conformance tests to the e-health strategy as well as offering relevant training. Thus the three phases of the Architectural components framework for e-health interoperability implementation (Figure 4.13) are the planning phase, implementation phase and enforcement phase.

The sustainability of e-health interoperability implementation is an important issue, especially in a developing country context. According to Sibuyi and Horner (2020) the sustainability of e-health programs is a critical topic, especially in developing country contexts. Considering that developing countries have unique factors and environments that impact sustainability, international donors and governments are concerned about the aspect of sustainability (Sibuyi & Horner, 2020). These stakeholders do not want donor-funded programs to halt as a result of sustainability issues. Similarly, digital health systems in economically developing nations are equally affected.

Additionally, Fanta and Pretorius (2018) posit that ensuring the sustainability of e-health systems is still a challenge in resource-constrained settings such as developing countries. Fanta and Pretorius (2018) maintain that most e-health projects either discontinue or fail to scale up soon after the pilot stage, a phenomenon known as "pilotitis". Leon et al. (2012) proposed a framework for analysing the sustainability of implementing m-health systems used in community based health services, in a developing country context. This framework consists of four dimensions namely: government stewardship, technological factors, organisational factors, and funding. This framework looks into the sustainability of m-health implementations and is not limited to checking the technical feasibility of the health information systems. Since this framework by Leon et al. (2012) was applied for the sustainability of m-health implementation, it can equally be applied for the sustainability of e-health systems interoperability since both are in the domain of e-health.

The Activity framework for implementing e-health interoperability in a developing country context (Figure 4.12), proposed by this research study, covers the four dimensions articulated in the sustainability framework developed by Leon et al. (2012). In this Activity framework the technological factors and organisational factors appear under barriers to e-health interoperability. E-health interoperability can also be one way of promoting e-health sustainability. The technological and organisational factors proposed by Leon et al.'s framework are also addressed in Figure 4.12 (Activity framework) in the same context. One aspect impacting the sustainability of digital health systems is funding. The funding dimension falls under stewardship, the term steward also means sponsor/champion, and definitely involves the financing part. The dimension, government stewardship is addressed in the national e-health strategy. In their sustainability framework, Leon et al (2012) infer that m-health projects that had government level policy support and stewardship are likely to be more sustainable than those that were initiated by individual organisations and implemented only at that level.

5.6 Summary

Chapter 5 narrated the study's findings and discussed of the research outcomes. The results were discussed with respect to thematic analysis of interviews, data analysis using NVivo12 and document review. The framework for implementing e-health interoperability was also presented. This research study revealed that several health information systems were identified by participants including Human Resources systems, Aggregate information systems, Laboratory Information systems, Administrative systems and HISs for HIV/AIDS. The maturity level of e-health systems implementation was reported to be low. The research findings indicated that Zimbabwe's e-health interoperability status is low, just like in other developing countries. Four types of barriers or impediments to e-health interoperability were also revealed by the study namely: technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers. The study revealed several enablers to e-health interoperability that include: the existence of a worldwide technical community supporting OpenHIE; the presence of NGOs such as HITRACT that are providing leadership and taking initiative; development of re-usable software components hence no need to reinvent the wheel; options of using cloud services to address lack of infrastructure and skills; as well as regional conformance testing as a strategy for promoting interoperability. The effects of lack of interoperability affirmed by this study are: health records cannot be shared, wastage of resources, wastage of drugs and high cost of healthcare to the patient and the government. The study disclosed that Nvivo analysis and document review largely confirmed the outcomes from interviews. Data collected through interviews informed the development of a dual framework for implementing e-health interoperability in Zimbabwe.

CHAPTER 6

SUMMARY, CONCLUSION AND FUTURE RESEARCH DIRECTIONS

6.1 Introduction

This research study investigated on implementing e-health interoperability in developing country contexts, so as to provide better care for patients. The study design was a qualitative study, employing the case study method. Several e-health stakeholders and key informants were interviewed on the status of e-health implementation in Zimbabwe, the status of e-health interoperability in Zimbabwe, and the consequences of a lack of interoperability in healthcare. Responses from the study's participants informed the development of the framework for implementing e-health interoperability which was meant to provide guidance of what countries could do when implementing e-health interoperability.

The study had the following specific objectives:

1. Determine the current status of e-health implementation in Zimbabwe;
2. Determine the current status of e-health interoperability in Zimbabwe;
3. Determine the barriers in the implementation of e-health interoperability a developing country context;
4. Determine the enablers in the implementation of e-health interoperability in a developing country context;

5. Identify the consequences of a lack of interoperability in a developing country context;
6. Develop a framework for implementing e-health interoperability in a developing country context.

The literature review served a dual role namely, mapping the theoretical and conceptual framework, as well as reviewing literature related to e-health interoperability. The Framework for Enterprise Interoperability (FEI) by Chen and Daclin (2006) formed the basis of this study's theoretical and conceptual framework. The related literature was reviewed and presented in terms of sub-items that include: the WHO framework for enhancing healthcare systems in economically developing countries; an overview of Zimbabwe's health system; WHO global diffusion of e-health; an overview of e-health systems implementation in Zimbabwe; interoperability standards and interoperability architectures.

This research study pursued an interpretivist research philosophy. The research design undertaken was qualitative and was carried out in the form of a case study method. Data was collected through semi-structured interviews from various e-health stakeholders. Document analysis was conducted in order to compare and corroborate findings from interviews. The four types of documents that were analysed were: national health planning documents; government acts, bills, policies and charters; e-health interoperability documents and reports on health systems. The main outcomes of the study are summarised in the paragraphs that follow, including the proposed framework.

6.2 Findings

This section summarises the research study's key findings. These are in terms of the current status of e-health implementation in Zimbabwe, current status of e-health interoperability in Zimbabwe, barriers in the implementation of e-health interoperability a developing country context, enablers in the implementation of e-health interoperability a developing country context, consequences of a lack of interoperability in a developing country context, Framework for implementing e-health interoperability in a developing country context.

6.2.1 The current status of e-health implementation in Zimbabwe

Findings for the current status of e-health implementation in Zimbabwe were two parts namely, the types of health information systems being used and the maturity level of digital health systems implementation.

6.2.1.1 Types of Health Information Systems (HISs)

The following types of health information systems are being used in healthcare in Zimbabwe: HIV/AIDS systems (ePMS, HIV macro database and ePOC); laboratory information systems (LIMS, Lab263); pharmacy (Dispense ware); administrative systems (HRIS, Practice Management Information System, PFMS, SAP healthcare and IMMIS); point of care systems (EHR); aggregate systems (DHIS2); logistics information systems (Navision) and radiology systems (PACS). Masuku (2019) acknowledged the operation of the following electronic HIS in Zimbabwe: DHIS2, IMMIS, ePMS, Laboratory Management Information System, Rapid Disease Notification System (RDNS) and the HIV Information Management System. In addition to these systems Chawurura et al (2019) added the PFMS. Furthermore, Chawurura et al. (2019) acknowledged the existence of additional several projects and experiments that the Ministry of Health and Child Care together with its partners were involved in namely, the national EHR (its development and piloting), the notification of maternal deaths, the piloting of tele-health in the Manicaland province, the monitoring of clinical mentoring and the implementation of e-partograph. The electronic health information systems identified by this study's participants are aligned to those implemented in other developing countries such as Tanzania, Zambia, South Africa and Uganda. However, this study's findings suggest that more electronic health information systems were identified by participants compared to those reported in literature.

6.2.1.2 Maturity level of e-health systems implementation

The maturity level of e-health implementation in Zimbabwe was reported to be low. Almost all the respondents evaluated the maturity level as low. The maturity level of e-health systems implementation was perceived in terms of the extent to which systems for digital healthcare were being used in the country and the number of e-health systems deployed nationwide. The study revealed that most health facilities were using manual health information systems and that electronic health information systems were deployed in a few selected facilities, thus the low level of e-health systems implementation.

6.2.2 The current status of e-health interoperability in Zimbabwe

Findings for the current status of e-health interoperability in Zimbabwe were in three parts namely: the overall status of e-health interoperability in Zimbabwe, interoperability barriers and interoperability approaches.

6.2.2.1 Overall status of e-health interoperability in Zimbabwe

The research study revealed that e-health interoperability was generally low. It was also reported that only the national EHR system was interoperable with DHIS2 and ePMS. In addition, the majority of the health information systems such as LIMS, HRIS, IMMIS and Navision were being used only in the public sector and could not communicate (interoperable) to those HISs in the private sector. The low level of e-health interoperability in Zimbabwe concurred with the situation in other African countries. For example, it was reported that in Tanzania that almost 86% of the HISs were not interoperable (Kajirunga & Kalegele, 2015).

6.2.2.2 Interoperability barriers

In accordance with this study's theoretical framework by Chen and Daclin (2006), four classes of barriers (obstructions) to interoperability were adopted namely: technological barriers, organisational barriers, terminology barriers as well as legal and regulatory barriers.

Technological factors

According to Chen and Daclin (2006), examples of technological barriers hindering interoperability are: operating systems, infrastructure as well as incompatibilities. It was also reported that work was in progress regarding developing an interface to enable SAP and DHIS2 to be able to communicate in Zimbabwe.

Organisational factors

Organisational barriers refer to incompatibilities of organisational structure and management styles. The study revealed that roles and responsibilities of individuals should be clearly defined so that conflict is eliminated. In addition, change management is required for stakeholders to positively embrace interoperability in healthcare. Challenges of inadequate skills and the need for innovative training approaches were also highlighted.

Terminology factors

Findings from the study pointed out that standards are critical as far as accomplishing e-health interoperability is concerned. The study revealed that the following e-health interoperability standards were employed in the national EHR system, ICD-10, CPT and ICPC-2. It was also reported that the HL7-FHIR standard was not yet implemented in the running HIS, although it is a common e-health interoperability standard.

Legal and regulatory factors

It was reported that Zimbabwe's health system did not address legal and regulatory issues pertaining to e-health. The absence of an e-health interoperability regulatory framework and national e-health policy at national level hampered e-health efforts in the country. The study revealed that in addition to an e-health regulatory framework, there was a need to promote conformance to set standards using events such as hackathons and regional connectathons.

6.2.2.3 Interoperability approaches

In this study, participants advocated for a loosely coupled approach over a closely coupled approach. These findings are also consistent with Romero and Vernadat (2016) cited in Turk (2020) that the trend is towards developing more loosely coupled systems over pre-defined and rigid solutions (closely-coupled systems). Loosely coupled systems promote rapid enterprise evolution and enhance e-business agility. This study also proposed a loosely coupled approach through the OpenHIE architecture. Using an interoperability architecture such as the OpenHIE, disparate systems can conform to the same architecture to enable interoperability. Participating systems might require minimal changes but would maintain their local autonomy which are characteristics of a loosely coupled approach.

6.2.3 Barriers in the implementation of e-health interoperability in a developing country context

This study revealed the following barriers to e-health interoperability:

- Issues of donor-funding;
- Challenges of human resources and skills (i.e. training of software developers and university education not preparing students effectively for roles in e-health);
- Limited participation of medical specialists in work on terminology issues in Zimbabwe;
- No policy framework guiding work on interoperability;
- Lack of stewardship on issues of interoperability in Zimbabwe;
- Challenges of security;
- Challenges of data sharing;
- Siloed development still dominant

6.2.4 Enablers in the implementation of e-health interoperability in a developing country context

This study revealed the following enablers to e-health interoperability:

- Existence of a worldwide technical community supporting OpenHIE;
- Presence of NGOs such as HITRACT that are providing leadership and taking initiative;
- Presence of local champions for OpenHIE in some countries, for example in Lesotho;
- Development of re-usable software components, no need to reinvent the wheel;
- Options of using cloud services to address lack of infrastructure and skills;

- Train the trainer approach to transfer of skills;
- Availability of global e-health goods, OpenHIE is an example of a global e-health good;
- Regional conformance testing as a strategy for promoting interoperability.

6.2.5 Consequences of a lack of interoperability in a developing country context

The study revealed several consequences of non-interoperable health systems for patients, the health workforce and governments. The following effects were reported: burden on the health worker, health records cannot be shared, wastage of resources, wastage of drugs and high cost of healthcare to the patient and the government.

6.2.6 Framework for implementing e-health interoperability in a developing country context

A dual framework for implementing e-health interoperability in developing country contexts was developed. The framework consists of an Activity framework (Figure 4.12) and an Architectural components framework (Figure 4.13). The study revealed that developing countries can build interoperability at the start of implementation of e-health rather than to fit it retrospectively. Owing to the fact that e-health interoperability is still at its infancy, it is possible to incorporate interoperability during the development of e-health systems.

Regional conformance testing is a critical activity since it ensures cross border interoperability. Regional conformance tests are more preferable in our African context because resources can be pooled together and have interoperability introduced in several countries, since developing countries are constrained on resources. Implementing interoperability using the country-by-country approach is likely to be more expensive for developing countries because of constraints on resources. Technical communities should also be formulated for purposes of providing support in contexts where personnel and skills are a challenge. In addition, there is a need for multiple strategies to promote the transfer of skills and development of personnel involved in implementation of interoperability in developing countries. The OpenHIE community of practice can be useful is this regard. Finally, there is a need to leverage global health goods to access funding and promote sustainability in the implementation of interoperability in developing countries.

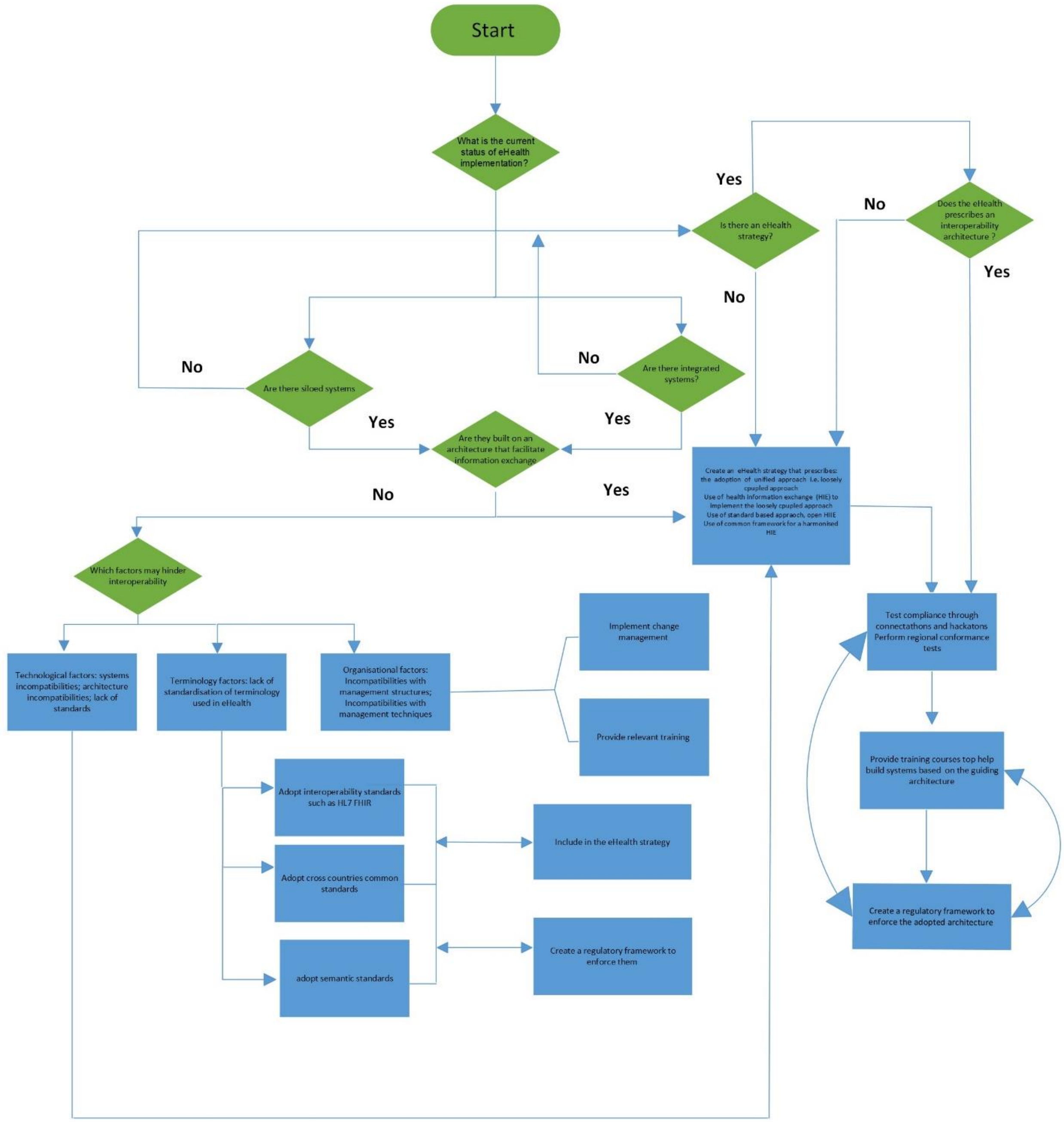

Figure 5.12: Activity framework

Figure 6.12 illustrates the detailed steps to be followed by governments of developing countries when implementing e-health interoperability.

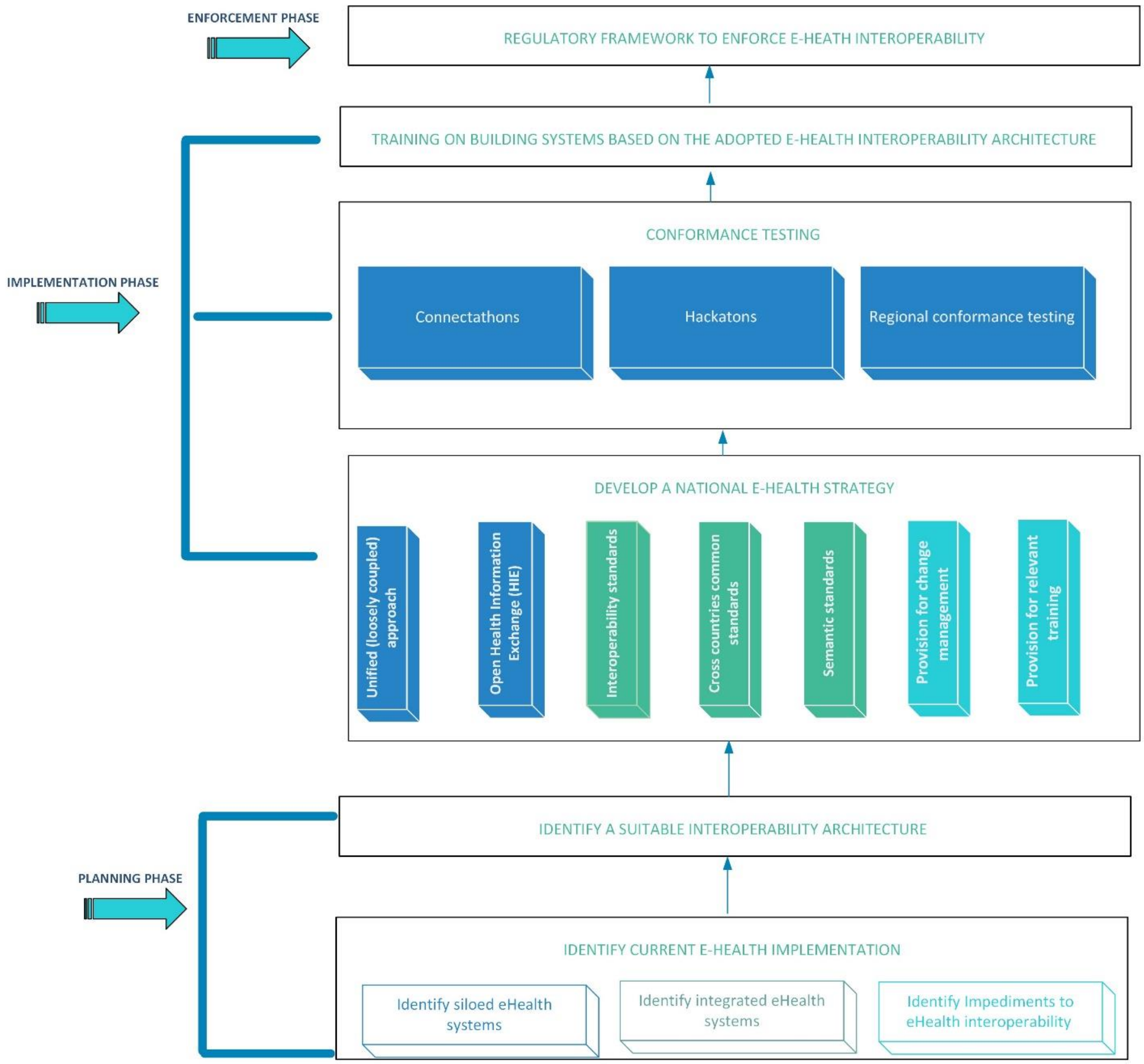

Figure 5.13: Architecture and components

Figure 6.13 depicts the Architectural components framework to guide the implementation of e-health interoperability in developing countries. This framework (Figure 6.13) comprises 3 phases namely: the planning, implementation and the enforcement phases.

6.3 Implications of the study

6.3.1 To policy

The study proposed an in-depth framework for implementing e-health interoperability in Zimbabwe. Since there was no policy on e-health interoperability in Zimbabwe by the time of publication of this thesis, the proposed framework could be a starting point for the health ministry in the country. By proposing a dual framework (activity frameworks as well as architecture and components) for implementing e-health interoperability in a developing country context, the research study provided the essential empirical evidence in that domain.

6.3.2 To theory

The research study identified gaps in literature. In addition, the study's theoretical framework was used to develop the conceptual framework. The research study's findings have contributed to addressing some of the gaps in the existing theory. Future research studies could also use this study as a reference point.

6.3.3 To practice

The study explored the implementation of e-health interoperability in developing country contexts using Zimbabwe as a case. The study proffered the necessary empirical evidence in this respect such as conformance testing via hackathons and connectathons. The findings could be leveraged for improved practices in the implementation of e-health interoperability in developing country contexts.

6.4 Recommendations

Since this study was problem-driven, the recommendations proffered are in line with what should be done to implement e-health interoperability in Zimbabwe.

1. Given that the status of e-health interoperability is low in Zimbabwe, there are barriers to interoperability that must be addressed. These are technological barriers, organisational, terminology as well as legal and regulatory barriers.

2. ICT and telecommunication infrastructure upgrade and expansion is required to facilitate health information exchange. Change management is required for stakeholders to positively embrace interoperability in healthcare. Clearly defined roles and responsibilities in organisations are vital so that conflict is eradicated.

3. It is recommended that the Ministry of Health and Child Care together with the Ministry of ICT ensure that e-health standards are implemented in all electronic health information systems so as to enable disparate systems to exchange health information systems. Both semantic and syntactic standards for interoperability should be employed. Accordingly plans should be in place to train the appropriate technical personnel on standardisation.

4. With the study revealing the absence of legal statutes specific to e-health, it is recommended that the Ministry of Health and Child Care together with the Ministry of ICT as well as other relevant stakeholders belonging to the healthcare field spearhead the development of a policy for e-health, an e-health framework and an e-health strategy to guide

and inform endeavors in e-health interoperability. Efforts should also be made to have periodic e-health strategies. Currently the country is using the Zimbabwe e-health strategy draft (2012-2017). In addition, there should be legislation that prescribes compulsory e-health standards as well as issues of confidentiality, privacy and security of patient data. Matters to do with creation, access, updating of patient data, patient consent and archiving of patient-related records should also be clarified to avoid consequences.

5. It is recommended that a loosely coupled approach be adopted for implementing interoperable electronic health information systems. In this approach individual systems are weakly-linked to each other such that changes in one system slightly affect the performance or existence of the other systems.

6. With regards to the proposed framework for e-health interoperability, it is recommended that a regulatory Board for electronic health be formed for purposes of monitoring and promoting conformance to standards, amongst others. Connectathons and hackathons are also recommended as platforms for compliance testing. In the African context, regional conformance tests are recommended because resources can be pooled together and have interoperability introduced in several countries, since developing countries are constrained on resources.

6.5 Limitations of the study

One significant study limitation was that the study participants did not include those from the Ministry of Information and Communication Technology (ICT) whose contributions would have been beneficial for this study on e-health interoperability. The researcher faced challenges in accessing their offices. Nevertheless, the researcher took advantage of some of the participants who had a strong background in Information technology (IT). This challenge was addressed by the inclusion of respondents who had a strong background in ICT. Four of the respondents had an undergraduate degree in Computer Science, Information technology or Information Systems.

6.6 Future research direction

The proposed framework was developed based on interview findings, but was not validated. In this regard, validation of this framework would be necessary in order to ascertain its usefulness and applicability. In addition, the validation should be conducted by a team of e-health stakeholders that is different from those that were interviewed. This would enhance objectivity and eliminate bias.

This research study was limited to electronic health information systems. A further study could incorporate other forms of e-health, for example mobile health (m-health) so that the framework ensures the interoperability of more than one forms of e-health. Such a study would assist with comparing insights and opinions from the two scenarios and moreover shed more light with respect to e-health interoperability in Zimbabwe.

Another future research direction could consider the use of hackathons in promoting regional conformance testing. Hackathons have been included in the study framework, this future research direction would consider particularities of hackathons and other details related to hackathons in relation to e-health interoperability.

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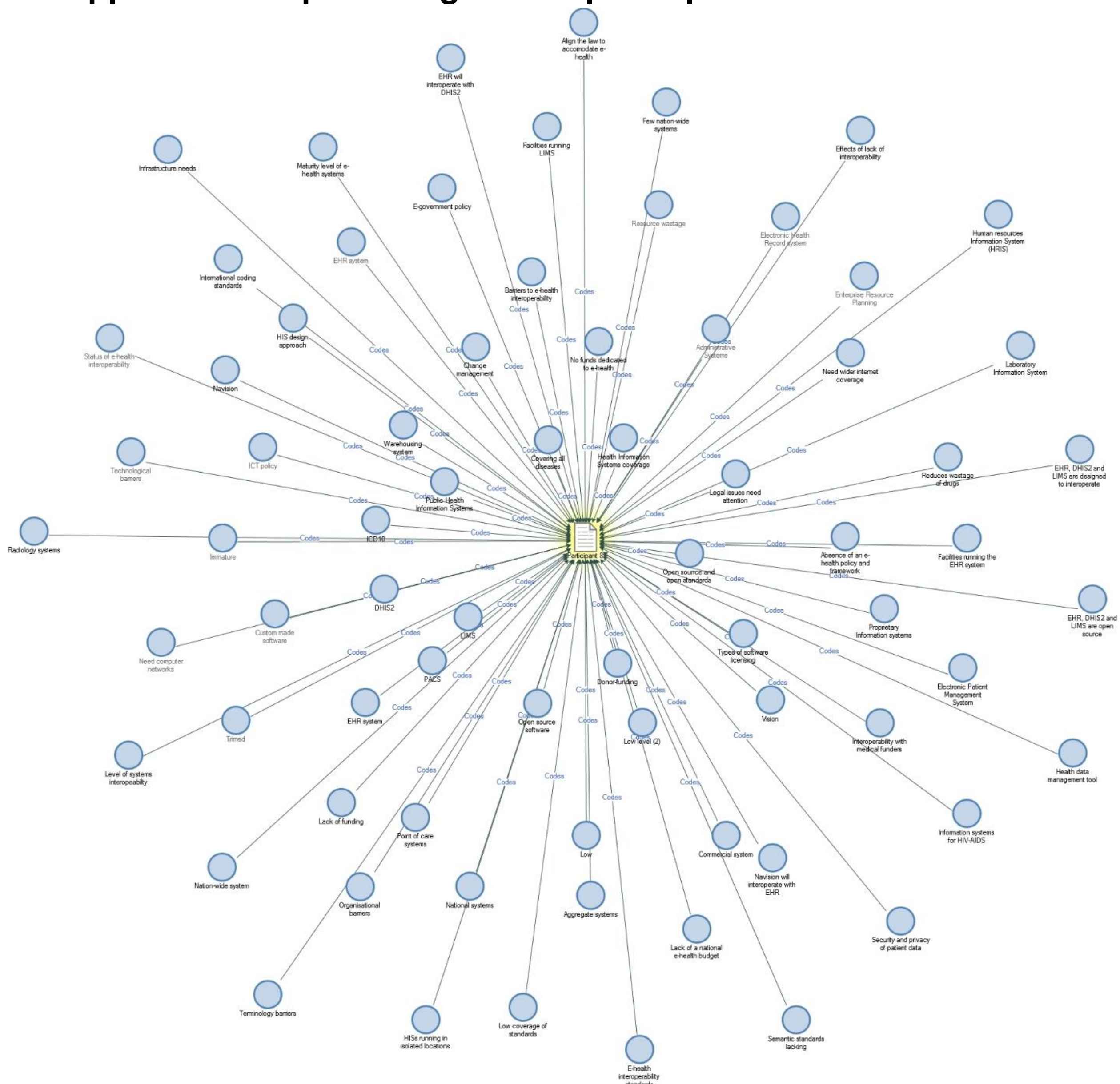
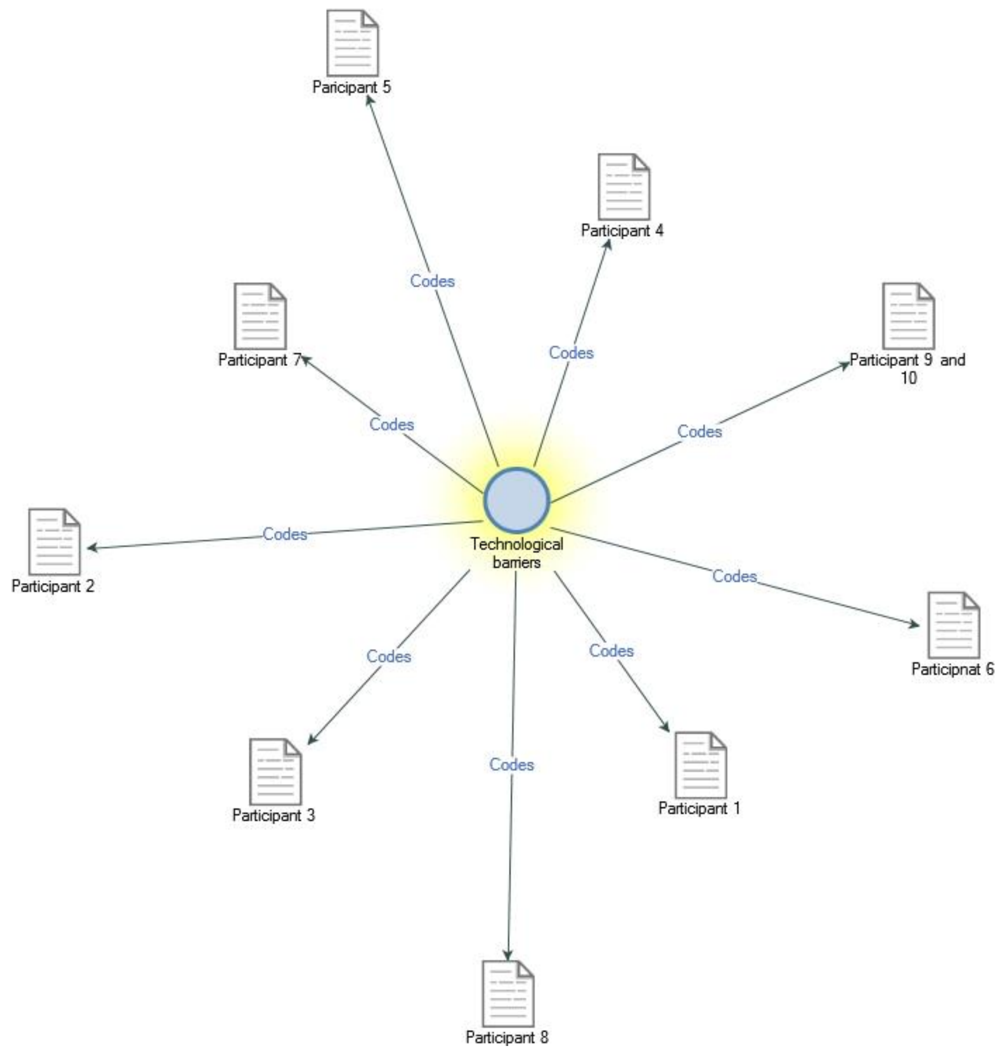
8.APPENDICES

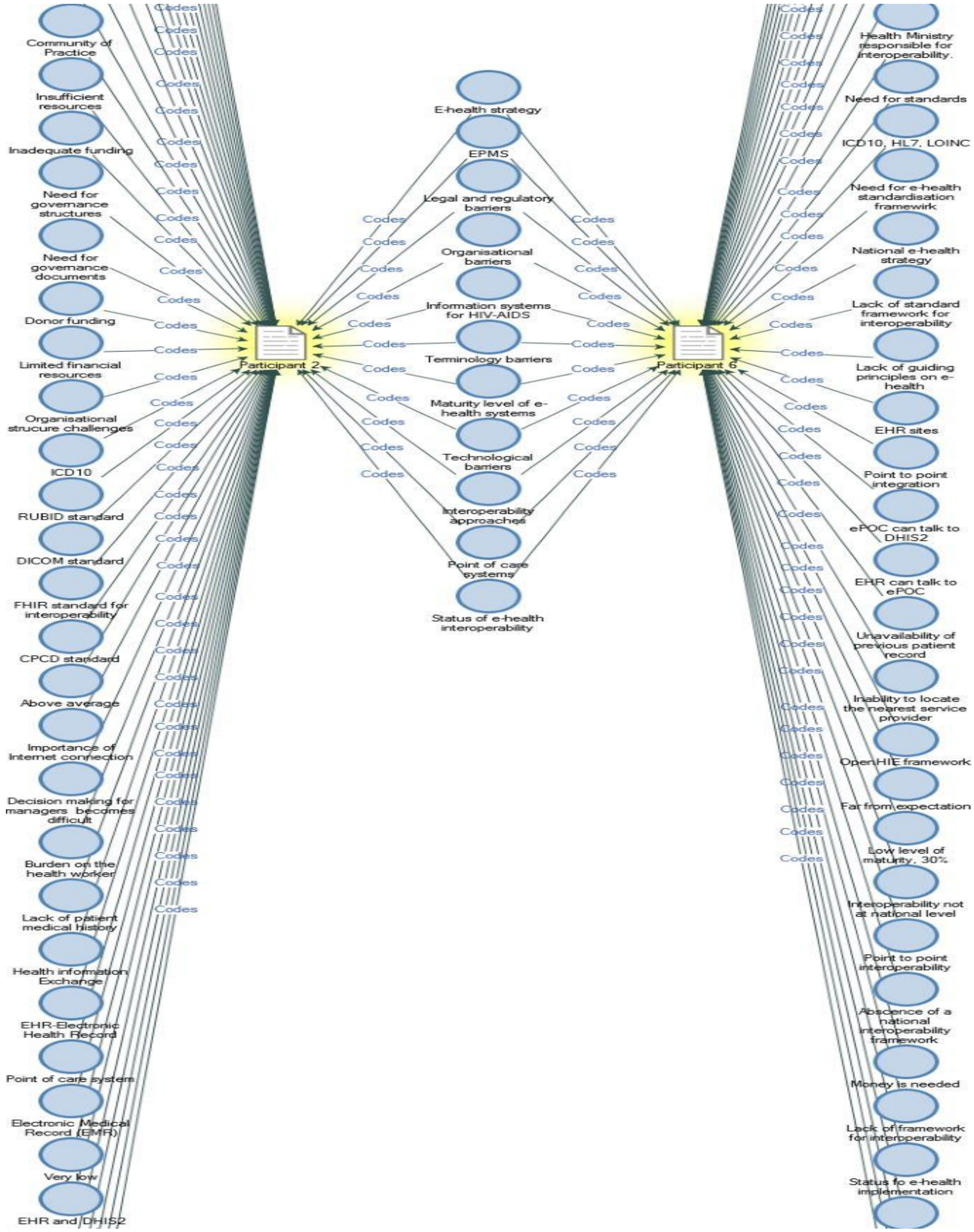
8.1 Appendix A: Explore diagram for participant 8



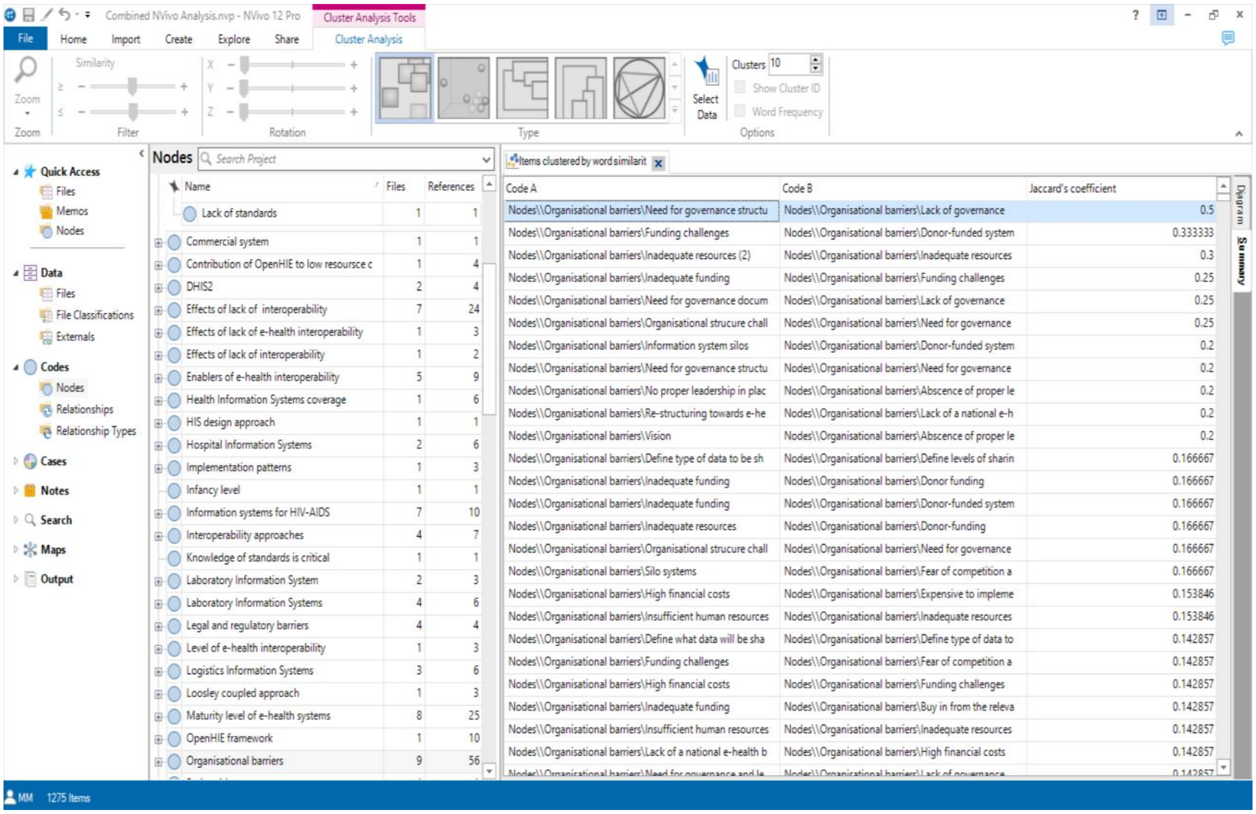
8.2 Appendix B: Explore diagram for technological barriers



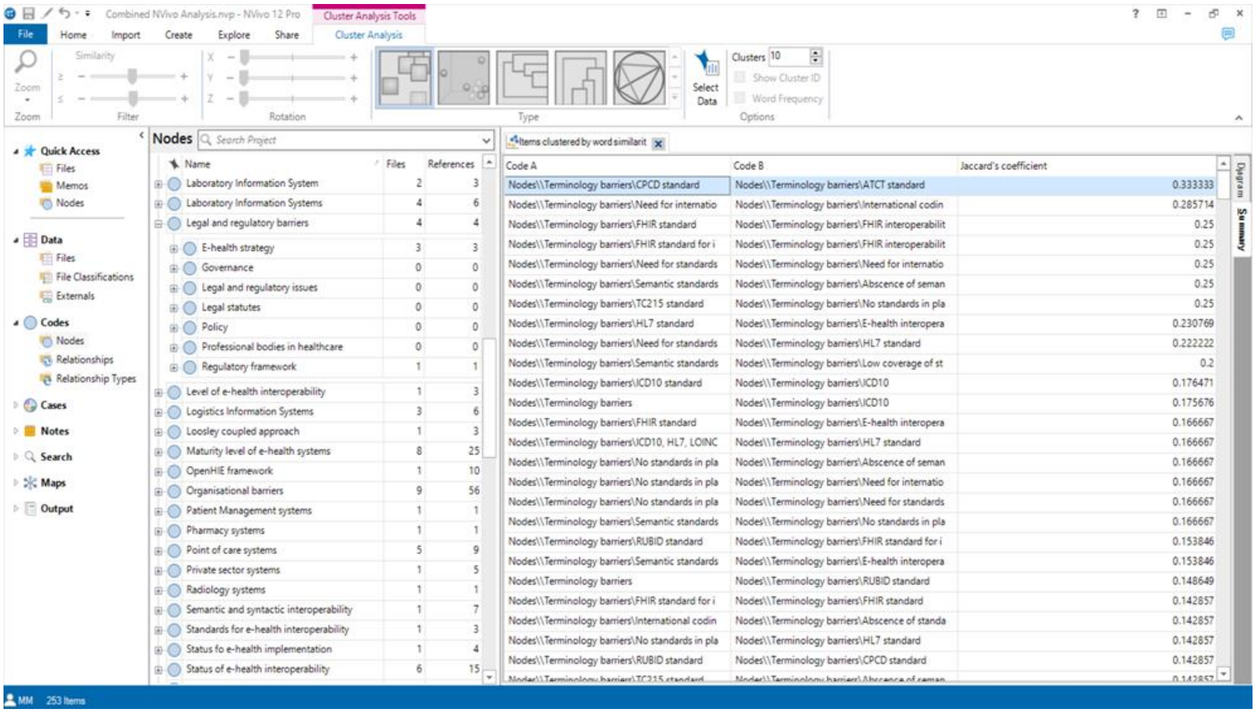
8.3 Appendix C: Comparison diagram for participant 2 and participant 6



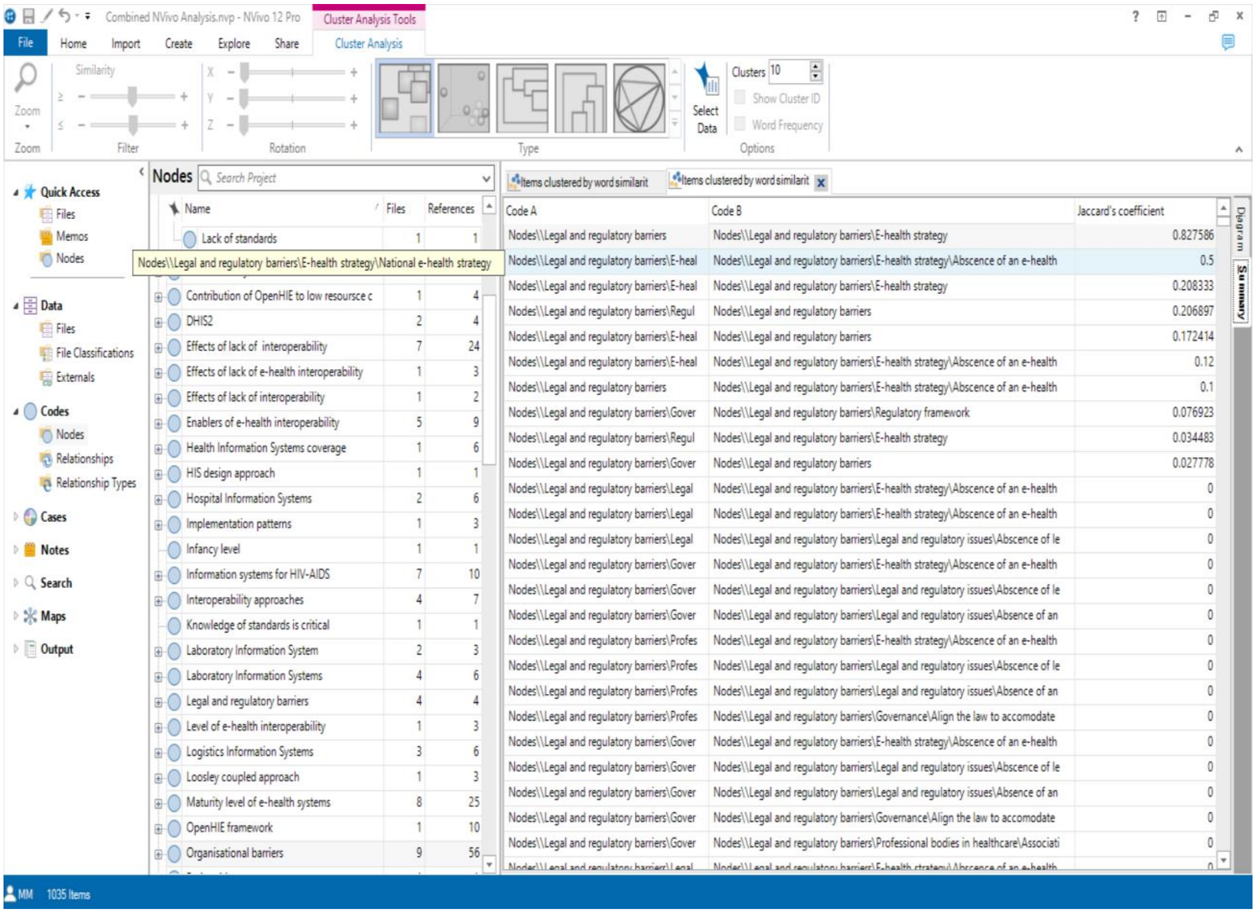
8.4 Appendix D: Jaccard's co-efficient for organisational barriers



8.5 Appendix E: Jaccard's co-efficient for terminology barriers



8.6 Appendix F: Jaccard's coefficient for e-health strategy



Code A	Code B	Jaccard's coefficient
Nodes\\Legal and regulatory barriers	Nodes\\Legal and regulatory barriers\E-health strategy	0.827586
Nodes\\Legal and regulatory barriers\E-heal	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0.5
Nodes\\Legal and regulatory barriers\E-heal	Nodes\\Legal and regulatory barriers\E-health strategy	0.208333
Nodes\\Legal and regulatory barriers\Regul	Nodes\\Legal and regulatory barriers	0.206897
Nodes\\Legal and regulatory barriers\E-heal	Nodes\\Legal and regulatory barriers	0.172414
Nodes\\Legal and regulatory barriers\E-heal	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0.12
Nodes\\Legal and regulatory barriers	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0.1
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Regulatory framework	0.076923
Nodes\\Legal and regulatory barriers\Regul	Nodes\\Legal and regulatory barriers\E-health strategy	0.034483
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers	0.027778
Nodes\\Legal and regulatory barriers\Legal	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0
Nodes\\Legal and regulatory barriers\Legal	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0
Nodes\\Legal and regulatory barriers\Legal	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Abscence of le	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Abscence of le	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Absence of an	0
Nodes\\Legal and regulatory barriers\Profes	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0
Nodes\\Legal and regulatory barriers\Profes	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Abscence of le	0
Nodes\\Legal and regulatory barriers\Profes	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Absence of an	0
Nodes\\Legal and regulatory barriers\Profes	Nodes\\Legal and regulatory barriers\Governance\Align the law to accomodate	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\E-health strategy\Abscence of an e-health	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Abscence of le	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Legal and regulatory issues\Absence of an	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Governance\Align the law to accomodate	0
Nodes\\Legal and regulatory barriers\Gover	Nodes\\Legal and regulatory barriers\Professional bodies in healthcare\Associati	0

8.7 Appendix G: Interview guide

TITLE OF STUDY "IMPLEMENTATION OF E-HEALTH INTEROPERABILITY IN DEVELOPING COUNTRY CONTEXTS: THE CASE OF ZIMBABWE"

The duration of the interviews will be one hour each. The interviews will be carried out in the offices of the respondents or other appropriate meeting place. The main questions that will be asked of the respondents of this study will be the following.

1. Can you identify the e-health systems in use in Zimbabwe today? Could you list them according to their categories?
2. What is your assessment of the level of maturity of e-health systems implementation in Zimbabwe?
3. Are present resource allocations adequate for the implementation of e-health systems?
4. What is the current status of e-health interoperability in Zimbabwe?
5. What have been the successes in the implementation of e-health interoperability?
6. What have been the challenges in implementation of e-health interoperability?
7. What are the technological factors affecting e-health interoperability in Zimbabwe.
8. What are the organizational factors affecting e-health interoperability in Zimbabwe?
9. What are the terminology factors affecting e-health interoperability in Zimbabwe?
10. What are the legal and regulatory factors in e-health implementation in Zimbabwe?
11. What are the impacts of the lack of e-health interoperability?

END.

8.8 Appendix H: Ethical Clearance from UNISA

UNISA university of south africa

UNISA COLLEGE OF SCIENCE, ENGINEERING AND TECHNOLOGY'S (CSET) RESEARCH AND ETHICS COMMITTEE

23 October 2018

Ref #:	048/MM/2018/CSET_SOC
Name:	Ms Mary Muhonde
Student #:	58538259
Staff #:	

RECEIVED
2018 -10- 25

Dear Ms Mary Muhonde

Decision: Ethics Approval for 5 years (Humans involved)

Researchers: Ms Mary Muhonde, 8547 Ruvimbo 1, Chinhoyi, Zimbabwe, mmuhonde1@gmail.com, +263 267 212 3442, +263 77 297 4977

Project Leader(s): Dr Vincent Mzazi, hornevz@unisa.ac.za, +27 11 670 9057

Working title of Research:
A Maturity Model for E-health Interoperability in a Developing Country Context: The Case of Zimbabwe

Qualification: PhD in Information Systems

Thank you for the application for research ethics clearance by the Unisa College of Science, Engineering and Technology's (CSET) Research and Ethics Committee for the above-mentioned research. Ethics approval is granted for a period of five years, from 23 October 2018 to 23 October 2023.

1. The researcher will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the Unisa College of Science, Engineering and Technology's (CSET) Research and Ethics Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
7. No field work activities may continue after the expiry date (23 October 2023). Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.
8. Permission to conduct this research should be obtained from the Ministry of Health in Zimbabwe and each E-health Systems Developer and Vendor Organization prior to commencing field work.

Note:

The reference number 048/MM/2018/CSET_SOC *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Unisa College of Science, Engineering and Technology's (CSET) Research and Ethics Committee.*

Yours sincerely

Dr. B Chimbo

Chair: Ethics Sub-Committee SoC, College of Science, Engineering and Technology (CSET)

Prof I. Osunmakinde

Director: School of Computing, CSET

Prof B. Mamba

Executive Dean: CSET

8.9 Appendix I: Introductory letter from Supervisor

UNISA university of south africa

RE: Request permission to do data collection for PhD study

Dear Sir / Ms

This letter serves as support for the request to do data collection in your organisation by my student Ms. Mary Muhonde, student number 58538259. Her research is entitled: "A Maturity Model for E-health Interoperability in a Developing Country Context: The Case of Zimbabwe". Mary has obtained ethical clearance for her research from the Research Ethics Committee of the College of Science Engineering and Technology at the University of South Africa. Her documentation in this respect is attached.

Hoping that her request receives your favourable consideration.

Yours Sincerely

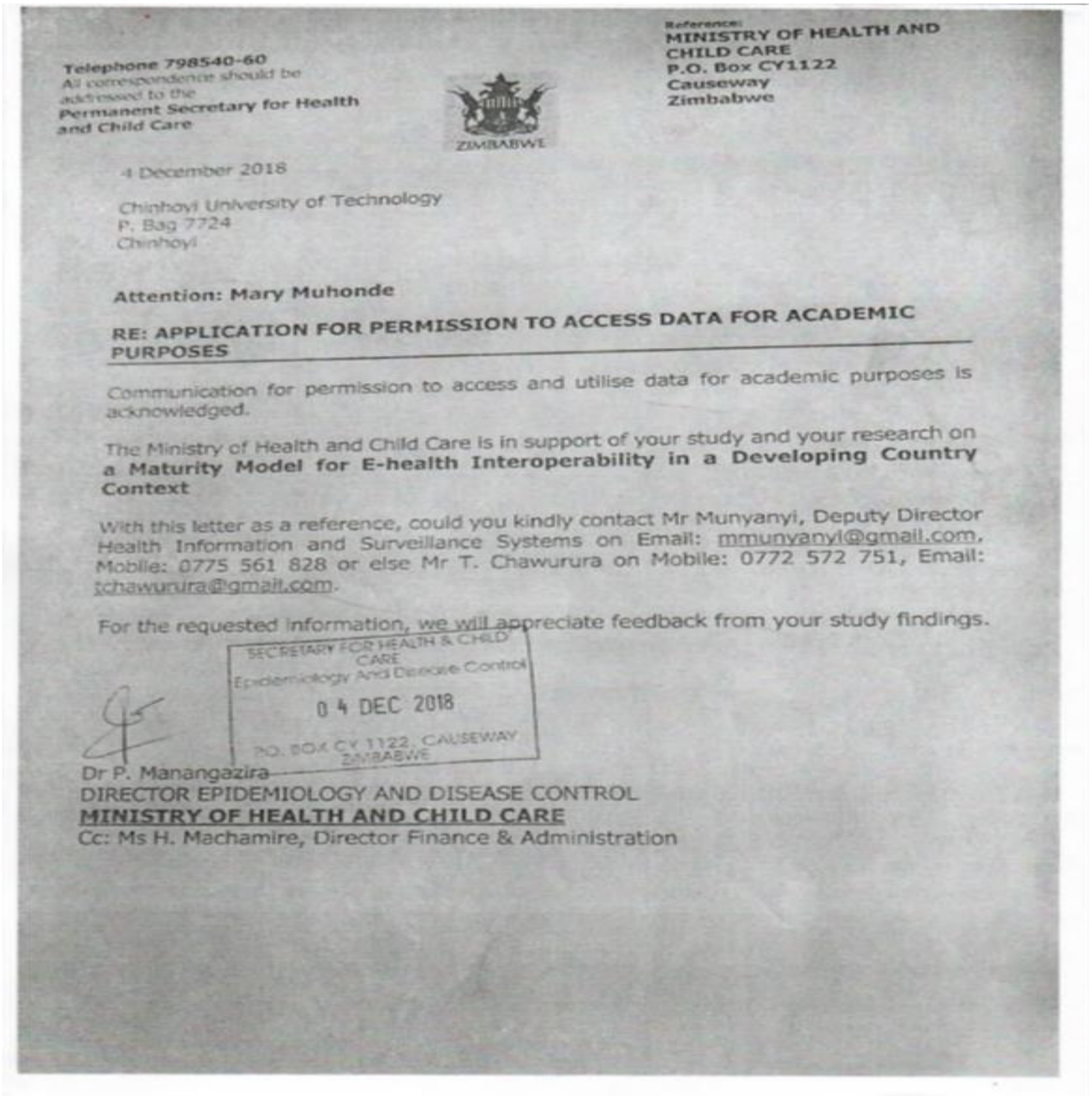
VMzazi
PhD (Community Health)
MSc (Computer Science)
(Senior Lecturer, School of Computing)

(Vice-chair ICT4D Flagship, College of Science Engineering and Technology,
University of South Africa)

learning with purpose assists the memory with retention - Leonardo

(Signature - V Mzazi)

8.10 Appendix J: Permission to gather data at Ministry of Health and Child Care



Telephone 798540-60
All correspondence should be addressed to the
Permanent Secretary for Health and Child Care

ZIMBABWE

Reference:
MINISTRY OF HEALTH AND CHILD CARE
P.O. Box CY1122
Causeway
Zimbabwe

4 December 2018

Chinhoyi University of Technology
P. Bag 7724
Chinhoyi

Attention: Mary Muhonde

RE: APPLICATION FOR PERMISSION TO ACCESS DATA FOR ACADEMIC PURPOSES

Communication for permission to access and utilise data for academic purposes is acknowledged.

The Ministry of Health and Child Care is in support of your study and your research on **a Maturity Model for E-health Interoperability in a Developing Country Context**

With this letter as a reference, could you kindly contact Mr Munyanyi, Deputy Director Health Information and Surveillance Systems on Email: mmunyanyi@gmail.com, Mobile: 0775 561 828 or else Mr T. Chawurura on Mobile: 0772 572 751, Email: tchawurura@gmail.com.

For the requested information, we will appreciate feedback from your study findings.

SECRETARY FOR HEALTH & CHILD CARE
Epidemiology And Disease Control
0 4 DEC 2018
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Dr P. Manangazira
DIRECTOR EPIDEMIOLOGY AND DISEASE CONTROL
MINISTRY OF HEALTH AND CHILD CARE
Cc: Ms H. Machamire, Director Finance & Administration

8.11 Appendix K: Permission to gather data at Health263

281 Hebert Chitepo Ave
Between 6th and 7th Avenues
Harare, Zimbabwe
Tel: +263 (242) 700431/2
+263 (242) 8677 004908/9
Website: www.health263.systems
email: sales@health263.systems

Att: Mary Muhonde

8547 Ruvimbo 1
Chinhoyi
Zimbabwe

26 November 2018

RE: REQEST TO CONDUCT AN ACADEMIC REASEARCH

In response to your request for permission to carry out an academic research in our organisation dated 20 November 2018, it is my pleasure to inform you that your request has been granted.

We will set aside resources to help you with the same and I hope the information they will provide will be helpful.

Wishing you all the best in your research study

Kind regards

(General Manager)

8.12 Appendix L: Permission to gather data at RTI – Zimbabwe

RTI INTERNATIONAL

Zimbabwe
32 Lawson Avenue, Milton
Harare. Zimbabwe
Tel: +263 7185025

Ms Mary Muhonde

Chinhoyi University of Technology
Chinhoyi
Zimbabwe

RE: REQUEST TO DO DATA COLLECTION FOR RESEARCH

As per your request dated 21 Nov 2018, it is with pleasure that I inform you that your request to collect data from our organization for research on the topic "A Maturity Model for E-health Interoperability in a Developing Country Context: The Case of Zimbabwe" has been granted. We require that data be used only for the purpose for which it is being collected for and that information will not be released or used in a way that may harm the interests or reputation of our organization. We understand and hope that detailed notes will not be shared in raw format but will be used and released in analysed format.

We hope this research will gather information that will assist in further development of e-health systems in Zimbabwe and beyond. Please share with us the reports and outcomes of your research.

We wish you the best in your academic endeavours.

Sincerely

Henry Chidawanyika

Chief of Party
RTI International – ZIMHISP Project

8.13 Appendix M: Certificate of language editing

CERTIFICATE OF ENGLISH LANGUAGE EDITING

This certificate confirms that the thesis below was edited by an expert English editor with a PhD and is ready for examination. The following issues were corrected: language, grammar, spelling, punctuation, sentence structure and phrasing, and proofreading.

Thesis Title

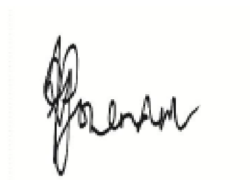
IMPLEMENTATION OF E-HEALTH INTEROPERABILITY IN DEVELOPING COUNTRY CONTEXTS: THE CASE OF ZIMBABWE

Author

Mary Muhonde

Date issued

5 October 2022



Dr Prinola Govenden

Language editor